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A DYNAMIC MODEL OF THE INITIAL
SPARES SUPPORT LIST
DEVELOPMENT PROCESS

William A. Allen, Captain, USAF
Jack A. Riess, Jr., Captain, USAF

LSSR 2-79A

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The Initial Spares Support List (ISSL) is an integral part of the Air Force initial provisioning process. Its purpose is to provide an adequate range and depth of spare/replacement parts to keep a newly activated end item in operation until normal supply channels are developed. Historically, the ISSL has provided either too few or too many parts. These inaccuracies have resulted in either excessive system down time or an excessive amount of money spent on spare/replacement parts. As a result of these problems, Air Force Logistics Command requested that a dynamic model of the ISSL development process be developed. The authors used the system dynamics approach to analyze the decision and policy making structure of the process. They constructed a dynamic model of the system and implemented the model on the computer with the DYNAMO simulation language. The model has been internally validated but needs to be verified with real world data. Once this has been accomplished, the model could be used as a tool to analyze the present ISSL policies and to experiment with revised policies in an attempt to provide more efficient support to Air Force end items.

LSSR 2-79A

# A DYNAMIC MODEL OF THE INITIAL SPARES SUPPORT LIST DEVELOPMENT PROCESS

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

By

William A. Allen, BA
Captain, USAF

Jack A. Riess, Jr., BS
Captain, USAF

June 1979

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This thesis, written by

Captain William A. Allen

and

Captain Jack A. Riess Jr.

has been accepted by the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN LOGISTICS MANAGEMENT

DATE: 13 June 1978

Thomas D. Clark Jr.
COMMITTEE CHAIRMAN

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## Chapter I

## INTRODUCTION

### Overview

The systems that are used by the Air Force are expensive, highly complex pieces of equipment that are continually being replaced with new systems in order to keep pace with both the changing enemy threat and the evolving state of American technology. These systems are procured through the weapon system acquisition process. This process is a sequence of specified activities that extend from the system conceptual phase through the full scale production and deployment of the weapon system (5:iii).

To ensure the initial operational capability of these newly acquired systems, support material in the form of spare and replacement parts must be available immediately upon system activation and through the initial phases of operation. These initial support requirements are provided by the initial provisioning process (5:iii).

The initial spares support list (ISSL) is a part of the initial provisioning process. Its purpose is to provide the initial range and depth of items required to support weapon system activations. The items that are included on the ISSL are determined at a provisioning conference by the technical equipment specialist, the system manager, the item manager, and representatives from the using command (6,8,11,13:12-30). The ISSL establishes a special inventory level at the base that is receiving the new system. Special levels

> . . . when used wisely . . . are valuable tools in effectively supporting operational activities; when the intent of special levels policy/procedures is abused, the overall ability of logistics managers to provide effective support is degraded [16:11-7].

Historically, the inventory levels established by the ISSL have been either too large or too small. In 1971 the ISSL stock levels were relatively large and the base level units complained that too much stock sat at base level without being used (7:1,8). A General Accounting Office study showed that in 1971 the Air Force spent several million dollars on spare/replacement parts which were never used (21:1). The next year, 1972, Headquarters Air Force Logistics Command (AFLC) implemented Department of Defense Directives that significantly reduced the ISSL stock levels. After the implementation of the new directives, the base level units complained that not enough stock was being provided by the ISSL to support weapon system activations (7:1,8).

The problem of inaccurate ISSL quantities still exists. As recently as March 1979, the overall Air Force parts use rate for ISSL items was 17% and, in particular, the parts use rate from ISSL stocks for the F-15 through March 1979 was 10% (2). On the other hand, AFLC continually receives requests to increase ISSL authorizations for other items (6). These facts indicate that there are still a significant number of cases in which the incorrect items in the incorrect quantities are being placed on the ISSL.

Because of this problem, AFLC requested that a study be initiated to develop a model of the ISSL development process (9:1). Two factors prompted this request: first, the procurement of too many or too few items during the provisioning process and, second, the apparent lack of understanding of the ISSL development process on the part of the Air Force logisticians who operate the Air Force supply system (2,6,8,11). Thus, the objective of this research effort was to develop a dynamic model of the ISSL development process. Specifically, a system dynamics approach was employed to develop a model of the system. This method was chosen because it provides a systematic approach to model construction through its treatment of ". . . the central framework underlying . . . activity [3:vii]." It provides a logical cause and effect means of analyzing the underlying management decisions that make up the ISSL development process.

While this research effort was directed towards the ISSL development process in general it specifically addressed Air Force managed economic order quantity (EOQ) items. In addition, the reader must keep in mind that the initial spares support list (ISSL) becomes a follow-on spares support list (FOSSL) ". . . once the weapon/end article has transitioned from the "initial" to "follow-on" support. . . [15:12-33]." The transition from ISSL to FOSSL is determined by ". . . the system manager (SM)/end article item manager (IM) ISSL/FOSSL monitor. . . [15:12-33]." Thus, this study applies not only to the ISSL, but to the FOSSL as well.

## Background

Through the weapon system acquisition process, the Department of Defense procures the weapon systems required to counter the threat posed by the forces of a potential enemy. The acquisition process is a sequence of specified activities designed to achieve program objectives. It extends from the system conceptual phase through the full scale production and deployment of the weapon system (5:iii). To ensure the initial operational capability of the newly acquired weapon system, support materials in the form of spare and replacement parts must be available on or before the system activation date. These initial support material requirements are satisfied through the provisioning process (5:iii).

During the initial provisioning process, decisions are made which can affect the future capability of DOD agencies to support their operational weapon systems. In addition, the initial provisioning decisions cause the expenditure of millions of dollars for spare and replacement parts (21:1). These provisioning decisions must be made in light of the initial provisioning objective of assuring

> . . . the timely availability of minimum initial stocks of support items at using organizations and at maintenance and supply activities to sustain the programmed operation of end items until normal replenishment can be effected, and to provide this support at the least investment cost [18:2].

The principle objective of initial provisioning, of which the ISSL is a part, is to assure the timely availability of initial stocks, at a minimum required level, at the using organization and maintenance activities to maintain the programmed operations of a weapon system until normal supply channels can be established. Moreover, this system support must be provided at the least possible cost (6,8,14:2-3).

The initial provisioning process is employed to procure needed support items that are not currently in the DOD inventory. These support items have been developed specifically for the weapon system and in many instances the support items themselves are made up of several separate subunits which must also be supported (13:1-1). The number and type of spare and support items required to initially support a weapon system are predicated upon the system's anticipated geographic deployment, mission profile, and the maintenance concept to be employed (13:1-8).

Two important factors used in determining the appropriate maintenance concept for a given spare or support item are the reliability and maintainability of the item. For the new items coming into the inventory the reliability and maintainability data are based on engineering estimates until actual failure rate data can be obtained from the operational use of the item (6,8,11, 15:12-3).

During the initial provisioning conference the reliability and maintainability data are considered along with any actual failure rate data in developing the ISSL. The ISSL is thus composed of those items that have been determined by the item manager/system manager,and representatives from the using command to be essential to weapon system operation for an initial period of time, and as such the ISSL is the central element of the initial provisioning process (15:12-5). Despite the coordinated efforts of the item manager, system manager, and the using command there have been numerous occasions where too few or too many items were included as part of the ISSL (2,6,8,11).

The procurement of too many or too few items can have a detrimental effect on the operational capability of the weapon system the ISSL is designed to support. The procurement of too few items results in an increase in the Not Mission Capable - Supply (NMCS) rate due to a lack of spare/replacement parts.

Conversely, the procurement of too many items results in the unnecessary expenditure of funds when the monies could have been better spent elsewhere (2,6,8,11). Because of these problems, AFLC requested that this research project be accomplished. The study used the system dynamics approach to analyze the ISSL development process.

## Justification

"Aircraft, missiles, engines, equipment, and other end articles coming into the inventory, . . . must be supported as soon as the end article(s) is received by the location/base from which it will operate [15:12-3]." These items constitute the end items procured by the DOD through its acquisition process. An integral part of the acquisition process is the initial provisioning process whereby spare and replacement parts are procured to support the end item until normal supply channels can be established (15:12-29).

The provisioning process is a series of critically timed actions designed to ensure that the new end items will have adequate support. The process extends ". . . over a wide range of functions, including design, maintenance planning, supply, requirements determination, item inventory control, procurement, cataloging, and contract administration [20:Encl 1-2]." This initial provisioning process ends with ". . . the delivery of a minimum range and quantity of support items. . . for support during an initial period of service [20:Encl 1-2]." These activities of initial provisioning bring the process into line with the stated DOD objective of providing the right part in the right place at the right time and in the right quantities. The DOD stated objectives of initial provisioning must be carried out under the concept of minimum supply response (18:2). The Air Force logistician is charged with the responsibility of achieving ". . . maximum initial support within available resources. . . under a concept that requires minimum supply response time [19:2]."

Minimum supply response is achieved through the attainment of a balance between ". . . pipeline inventory and costs related to holding inventory [19:2]." The implementation of this concept of minimum supply response is predicated upon the inventory policies providing for a coordinated approach to the elements of

> . . . program development; the depth of stocks provided in the initial requirements computation; the range of items selected for initial stockage; and the requirements computation policy. . .[19:2].

Therefore, the minimum supply response concept can be likened to the initial provisioning process in that both have the objective of ensuring that the base has ". . . available a given range and depth of stock to ensure acceptable support from the first day the end article(s) is assigned [15:12-3]." The range and depth of items to be provided are ". . . agreed to during the provisioning process

[15:12-3]." The concept of acceptable support is geared towards providing an adequate range and depth of spare and replacement parts to meet the programmed operations of the end item at the base level.

There are three important questions which must be answered during the provisioning process to determine the range and depth of items to be provided as part of the initial provisioning or ISSL package. These questions are: (1) how critical is the item considered for inclusion on the ISSL to weapon system operation; (2) what will the demand rate be for the item; and, (3) how much money is available for the purchase of these spare/replacement items (1:1)? The answers to these questions are difficult to ascertain particularly when an ISSL pertains to a new weapon system and the component reliability data are based on engineering estimates rather than actual operating performance (6). However, through application of the system dynamics approach and the resultant information-feedback model, potential decisions regarding levels of spare/replacement parts can be analyzed to ascertain the level of system support that will be provided by that level of support. By testing the different stock levels the Air Force logistician will be in a better position to meet the initial provisioning objective by providing to base level units an adequate and accurate ISSL.

During the initial provisioning process an inventory management specialist assigned to Headquarters, Air Force Logistics Command (AFLC) uses the engineering reliability data in conjunction with ". . . base order and ship time, base repair cycle and initial operating level. . . [9:1]," to determine the quantities required for each item chosen to become part of the ISSL (9:1-2). The mathematical models used by the inventory management specialist were developed by the Department of Defense and are contained in DOD Instruction (DODI) 4140.42. DODI 4140.42 gives the control of the variables used in the model to the headquarters level activity responsible for the logistical support of the weapon system (19:3). The Directorate of Materiel Requirements (LOR) in Air Force Logistics Command Headquarters is responsible for the calculations affecting the depth of items to be provided as part of the ISSL.

When calculating the number of a given item to stock as part of the ISSL, the specialist assigned to AFLC/LOR must work within the parameters established by the engineering specialist. While working within these parameters the LOR specialist must assume that the data supplied by the equipment specialist is accurate; thus making the initial requirements computations accurate. However, according to an inventory management specialist assigned to AFLC/LOR, the quantities of items carried on the ISSL are not always accurate as evidenced by the numerous requests for changes to the ISSL stockage level which are being received by AFLC/LOR (2,6,8,9:1,11).

Two examples of problems associated with an inaccurate quantity on a ISSL were given by a supply system analyst assigned to the Directorate of Logistics (AFLC/LOL). First of all he had a personal experience with an over stockage due to an inaccurate ISSL supporting an F-4E fighter squadron in Germany in 1972 (2).

The squadron was being supported by an ISSL which contained items valued at over $400,000. During the two year time span of the ISSL, only 14 per cent of the items were used. The result was that approximately $344,000 was invested in inventory that was not used. Some of this excess inventory was returned to the supply system with the remainder being disposed of as salvage material (2).

The second example concerned a problem that he was currently trying to solve. This second example also concerned an F-4E fighter squadron, but in this instance the fighters were assigned to the Alaskan Air Command. The problem revolved around the fighter squadron experiencing a 60 per cent Not Mission Capable-Supply (NMCS) rate because the ISSL did not specify an adequate range and depth of spare/replacement parts (2).

The first example serves to point out that when the engineering estimates on the reliability of components are used, the ISSL quantities can be high when predicting the depth of spare/replacement parts needed to support a weapon system during its initial period of service (2,6,8,11). The second example points out that as a system progresses through time, and the ISSL is adjusted for the "no demand generated" items, the range and depth of items specified for system support may be low. The low system support results because the "no demand generated" items are deleted from all future ISSLs so that new system/equipment activations will not have the items included when in fact the items may be needed; thus degrading the logistical support intended for the system. Logistical support was further degraded when the different type of operating environment for the F-4E was not taken into consideration when the required support items were specified for the Alaskan Air Command (2).

In the recent past, the ISSL estimates were predominantly high, which caused the expenditure of several million dollars for the procurement of spare/replacement parts which were not used (21:1). The high expenditure of funds caused the House Appropriations Committee to direct the General Accounting Office (GAO) to conduct an investigation into the initial provisioning practices of the Air Force (21:1). A 1971 GAO report stated

> The Air Force spends hundreds of millions of dollars annually to obtain spare parts needed to support new aircraft during an initial period of operation. . . . Initial provisioning is one of the most important activities of military supply. If not enough parts are purchased, operational capabilities of new aircraft can be reduced. If too many parts are purchased too soon, or if wrong parts are purchased, money is wasted or prematurely spent [21:1].

The report continued and said

The appropriations Committees of the Congress and other committees may wish to consider the matters discussed in this report in connection with future Air Force requests for spare parts to initially support new weapon systems [21:4].

As a result of this unfavorable GAO report, DOD directives were implemented by the inventory specialists at AFLC which significantly reduced the ISSL stock levels (7:1). The Inventory management specialists who were interviewed pointed out that the ISSL stock levels have become insurance items until normal supply channels can be established and each item on the ISSL has had an opportunity to go through its demand development period (2,6,8,11).

The demand development period extends from the item's preliminary operational capability date to that point in time when the item requirements ". . . can be forecast based upon actual demand or other empirical data indicative of the need for spare and repair parts [19:Encl 4-1]." The demand development period cannot exceed two years; however, in some cases the period may end in a relatively shorter period of time (19:Encl 4-1).

Other factors which the inventory specialists pointed out indicate that there is an inadequate feedback system due to an apparent lack of understanding of the ISSL development and adjustment process. Perhaps the most graphic portrayal of this lack of understanding occurs when the spare/replacement parts are requisitioned from the base supply system. For example, the requisitioning code oftentimes does not reflect the proper priority code; i.e., an expedite code is used instead of a routine code when applicable (2). The impact of these expedited requisitions is felt at the provisioning conference. The provisioning conference serves as a forum at which the system manager, item manager, and representatives from the using command meet to review and discuss the range and depth of items designated to become part of the ISSL (15:12-29). The major command representatives oftentimes comes to these conferences with requests for changes to the levels of certain items which are based on personal experiences, actual or historical, on similar items.

Once the ISSL has been established changes to the computed stock levels may be submitted to Directorate of Materiel Requirements (AFLC/LOR) for review and possible inclusion in the ISSL (2,6,8,9:1). Currently, AFLC policy authorizes units to submit requests for changes to the computed ISSL quantity levels, provided the changes are based on sound managerial judgement and submitted in writing to AFLC/LOR (6,8,9:1). The intent of this policy was to allow for unusual circumstances to be rectified. These written requests for changes to the computed levels were expected to be the exception rather than the rule. However, change request letters are continually being received and processed by AFLC/LOR, which indicates a lack of understanding of the ISSL process and its purpose by the using agencies (6,9:1).

To put the foregoing into perspective, the initial spares support list (ISSL) is designed to provide an adequate range and depth of spare/replacement parts at base level to support weapon system/equipment activations until normal supply channels can be established. The depth of items provided is fixed for 730 days unless actual demand exceeds the anticipated usage (15:12-29).

Based on the preceeding information the problem for our research effort is to develop a dynamic model of the ISSL development process. Since the steps applicable to a system dynamics approach will be employed in the model construction several research objectives were established and research questions were formulated to guide the research effort. These research questions and objectives were designed to uncover the structure of the ISSL development process because uncovering the structure of a system ". . . tells how the parts are related to one another [3:15]."

## Applying System Dynamics

System dynamics was selected as the approach to study the ISSL development process because it provides ". . . a way of studying the behavior of industrial systems to show how policies, decisions, [and] structure . . . are interrelated . . . [3:vii]." Another factor which prompted the application of system dynamics to this research effort was that the central activities of the ISSL development process are also found in the corporate activities towards which system dynamics is directed. In his book <u>Industrial Dynamics</u>, Forrester said

> . . . any economic or corporate activity consist of flows of money, orders, materials, personnel, and capital equipment. These five flows are integrated by an information network [3:vii].

Further, system dynamics ". . . recognizes the critical importance of this information network in giving the system its own dynamic characteristics [3:vii]."

In approaching the construction of a model of the ISSL development process system dynamics was attractive because it analyzes the real world system to ". . . determine how information and policy create the character of the organization [3:vii]," and permits the model to be used as a "management laboratory." The system dynamics approach requires a series of steps for the successful creation of the management laboratory. Two of the steps necessary for the successful application of system dynamics are

> . . . first . . . to identify the problems and goals of the organization. The second is to formulate a model that shows the interrelationships of the significant factors. Such a model is a systematic way to express our wealth of descriptive knowledge. . . [3:vii].

By applying system dynamics, the model was developed that revealed the behavior of the system as determined by the interactions of the system's variables. Perhaps the greatest benefit of a properly constructed model is that ". . . proposed changes can be tried in the model and the best of them used as a guide to better management [3:vii]."

The best support for the use of system dynamics is found in Jay Forrester's book Industrial Dynamics; the reader should note that industrial dynamics is synonymous with system dynamics. In Industrial Dynamics Forrester said:

> Industrial dynamics is the study of the information-feedback characteristics of industrial activity to show how organizational structure, amplification (in policies), and time delays (in decisions and actions) interact to influence the success of the enterprise. It treats the interactions between the flows of information, money, orders, materials, personnel, and capital equipment in a company, an industry, or a national economy.
>
> Industrial dynamics provides a single framework for integrating the functional areas of management--marketing, production, accounting, research and development, and capital investment. It is a quantitative and experimental approach for relating organizational structure and corporate policy to industrial growth and stability.
>
> Industrial dynamics should provide a basis for the design of more effective industrial and economic systems [3:13].

The ISSL development process of the Air Force supply system further lends itself to a system dynamics approach because it has all of the characteristics delineated by Forrester. These characteristics include an organizational structure, policies, decisions, information flows, money, orders, material, personnel, and capital equipment. In addition, the ISSL development process also includes areas which are equivalent to the functional areas found in private industry which include marketing, production, accounting, research and development, and capital investment. The distinct similarities that exists between the ISSL development process and the information-feedback structure of private industrial concerns make the system dynamics approach to model construction well suited to our needs.

Research Questions

The research questions that were addressed during this AFLC requested study were:

A. Can the pertinent dynamic interrelationships that produce the ISSL be identified?

B. Can the cause and effect relationships of the interacting variables be traced?

C. Can the control process be formulated to describe how decisions result from available information?

D. Can a mathematical model of the process, information sources, and interactions of the ISSL development process be constructed?

Research Objectives

The following specific research objectives were developed to guide this research effort towards the general objective of constructing a dynamic model of the initial-spares support list (ISSL) development process:

A. Determine the pertinent dynamic interrelationships that produce the ISSL. Identify the pertinent information-feedback structures that exist and how they interact to produce the range and depth of items required to provide end item support.

B. Trace the cause and effect relationship of the interacting variables. By accurately tracing the relationships that exist between the variables which have been determined to be pertinent, the central underlying structure of the ISSL development process will be revealed.

C. Formulate the control process to describe how decisions result from available information. The formal as well as informal control processes which result in the finalized ISSL must be studied to accurately represent how the published ISSL is determined.

D. Construct a mathematical model of the process, information sources, and interactions of the ISSL development process. The construction of a quantitative model provides a method of insuring that all pertinent variables have been included and that the constructed model accurately represents the ISSL development process.

E. Generate the behavior of the system through time by operating the mathematical model. Through operation of the model the applicability of the model to the system and its ability to duplicate the system will be revealed. For the ISSL development process, adequate end item support will be provided.

F. Test the internal and external validity of the model. In order for the model to be useful it must replicate the system being studied. For this to be possible all of the internal and external functioning of model must duplicate the actual system.

In the succeeding chapters the model of the initial spares support list (ISSL) development process will be described in conformance with the research objectives. Chapter II will address the methodology of the research effort and provides an introduction to system dynamics. Chapter III presents the interrelationships and the polarity of the relationship between the variables that make up the ISSL development process.

The control processes of the system will be formulated, and a mathematical model constructed in Chapter IV. Model operation and validation are discussed in Chapter V. Chapter VI presents a summary of the study, conclusions, and recommendations for further research.

# Chapter II

# METHODOLOGY

## Introduction

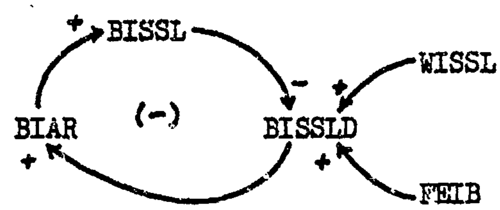
As indicated in Chapter I, system dynamics was employed to analyze the ISSL development process. Presented in this chapter are the system dynamics techniques of causal loop diagramming, flow diagramming, and equation formulation. This is followed by comments concerning model operation, validation, experimentation, and data sources. The discussion in this chapter is designed to prepare the reader for the technical discussion of the model in succeeding chapters. Causal loop diagramming is presented first.

## Causal-Loop Diagramming

Goodman both defined and stated the purpose of causal-loop diagramming. He said:

> System dynamics focusses on the structure and behavior of systems composed of interacting feedback loops. . . . Causal-loop diagrams identify the principal feedback loops without distinguishing between the nature of the interconnecting variables. . . . and play two important roles in system dynamics studies. First, during model development, they serve as preliminary sketches of causal hypotheses. Second, causal-loop diagrams can simplify illustration of a model. In both capacities, causal-loop diagrams allow the analyst to quickly communicate the structural assumptions underlying his model [4:5].

A relatively simple example from the ISSL development process model is presented in Figure 2-1 to illustrate the major structural features of a causal loop diagram. This diagram will be developed into a system dynamics flow diagram and a series of DYNAMO equations in later sections of this chapter.

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0025NOTE     BISSL   -BASE ISSL
0050NOTE     BISSLD  -BASE ISSL DISCREPANCY
0075NOTE     BIAR    -BASE ISSL ADJUSTMENT RATE
0100NOTE     WISSL   -WORLDWIDE ISSL
0125NOTE     FEIB    -FRACTION OF END ITEMS ON BASE
```

Figure 2-1. Example Causal-Loop

The three major components of the causal loop are its variables, the relationships between the variables, and the polarity of the loop. The variables are Forrester's ". . . factors that appear to interact to create the observed symptoms [3:13]." In the example, they are the Base ISSL, the Base ISSL Adjustment Rate, the Base ISSL Discrepancy, the Worldwide ISSL, and the Fraction of End Items on Base.

The relationship between a pair of variables is indicated by an arrow. The directional influence of the relationship is indicated by the direction of the arrowhead (4:6-7). Referring to the example, the Worldwide ISSL influences the Base ISSL Discrepancy, the Base ISSL Discrepancy influences the Base ISSL Adjustment Rate, and so on. The sign of the arrow indicates the type of influence. A critical assumption in determining the sign of a pairwise causal relationship is that all factors are held constant except for the variables in the relationship under consideration (4: 8). For example, when considering the relationship between the Worldwide ISSL and the Base ISSL Discrepancy, the Fraction of End Items on Base, the Base ISSL Adjustment Rate, and the Base ISSL are all considered to be constants. If the sign of the relationship is positive, then ". . . a change in one variable generates a change in the same direction in the second variable relative to its prior value . . . [4: 7]." In the example, an increase in the Worldwide ISSL results in an increase in the Base ISSL Discrepancy; similarly, a decrease in the Worldwide ISSL results in a decrease in the Base ISSL Discrepancy.

If the sign of the arrow is negative, ". . . a change in one variable produces a change in the opposite direction in the second variable [4: 7]." For example, as the Base ISSL increases, the Base ISSL Discrepancy decreases; conversely, as the Base ISSL decreases, the Base ISSL Discrepancy increases.

The polarity of the overall causal-loop is indicated by the + or - sign in parenthesis within the loop. If the polarity of the loop is positive, ". . . a change in one element. . . causes further change in the same direction in an unending process [4:26]."

If the polarity of the loop is negative, the loop is goal seeking (4:9); that is, there is a feedback mechanism present which

> . . . tends to keep a given system at equilibrium. In the most simple system, a single rate based on discrepancies between the desired goal and level drives the system to its goal value. Inflow or outflow rates readjust until the level reaches the desired value [4:51].

This is the case in the example. The polarity of the loop is negative; therefore, any influence that generates a Base ISSL Discrepancy will be countered by an adjusted Base ISSL Adjustment Rate until the desired Base ISSL level is reestablished.

After the entire ISSL development process was described to the point where the important variables and interrelationships were identified in a causal-loop diagram, system flow diagrams were developed.

Flow Diagramming

Flow diagramming is an intermediate step in developing a system dynamics model. Goodman stated that detailed flow diagrams must be constructed before simulation analysis can proceed from the causal-loop stage (4:12). Forrester stated that

> . . . a pictoral representation of an equation system is highly desirable. A diagram that displays the interrelationships between equations helps to lend clarity to the system formulation. . . . A properly constructed flow diagram is better than a set of equations for communicating the structure of a system to many practicing managers. A diagram represents an intermediate transition between verbal description and a set of equations [3: 81].

The standard symbols used in flow diagramming are illustrated in Figure 2-2 and briefly discussed below. An auxiliary variable represents a concept in the information flow channel that has an independent meaning. It can be algebraically substituted into a rate equation. A constant is a numerical value that does not change for the duration of the computation of a single model run. A decision function (rate) can be thought of as a "valve" that determines the rate of flow in a flow channel. A delay is a combination of levels and decision functions that modify the time relationships between the input flow which is given and the resulting output flow which is generated by the delay. A flow of information represents the passage of information within the system. A flow of resources is the passage of people, money, or materials into or out of the levels within the system. An information takeoff is the origin of an information flow. A level is the aggregation of resources within the system; it is analogous to inventory in a supply system. A source or a sink is an origin or destination of resources which lies outside of the boundaries of the model.

A system dynamics model is primarily concerned with levels and flow rates. Forrester said:

> A basic structure of alternating levels and flow rates seems to represent the nature of industrial management systems. The levels determine the decisions that control flow rates. The flow rates cause changes in the levels. These levels and rates make up six interconnected networks

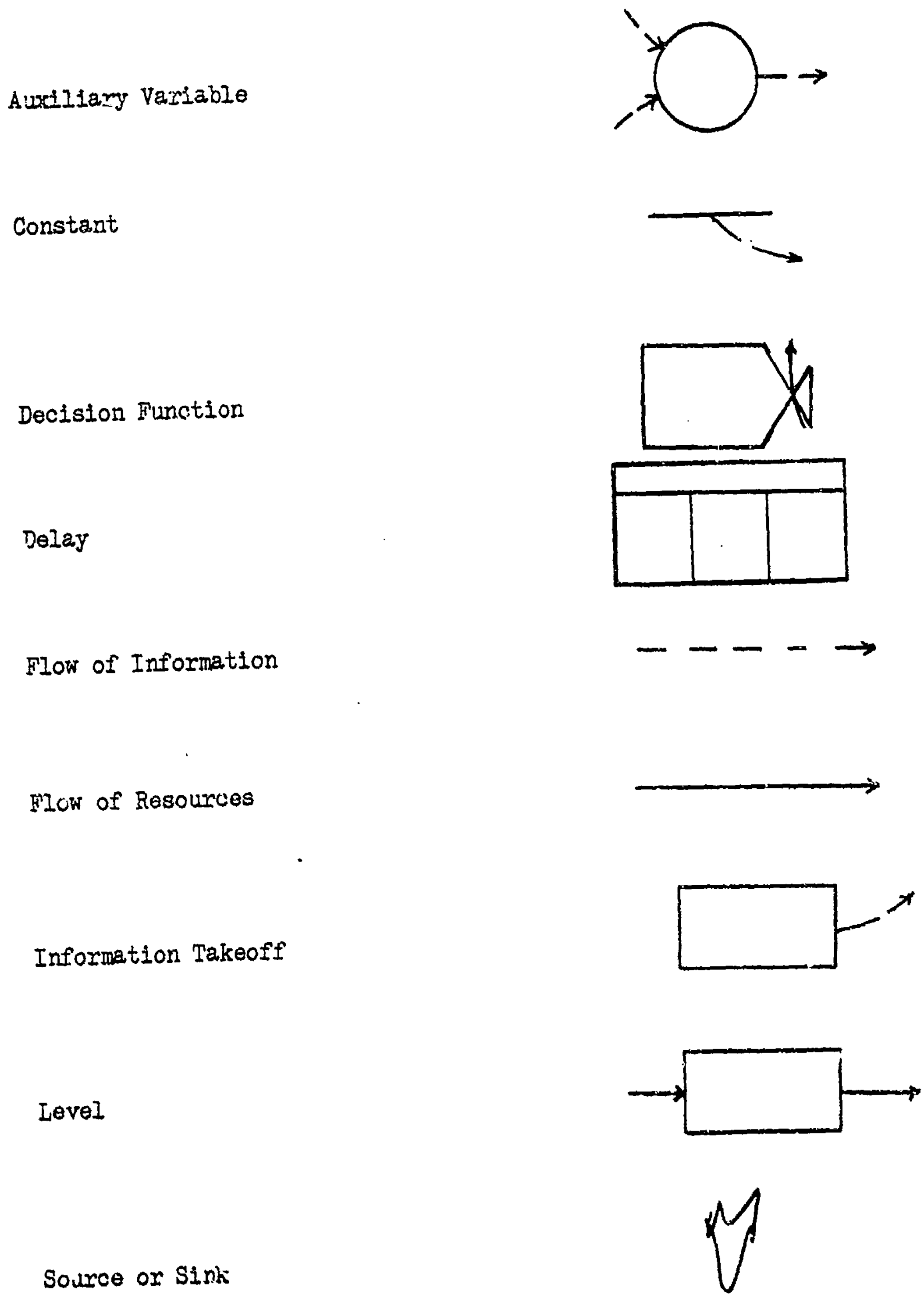
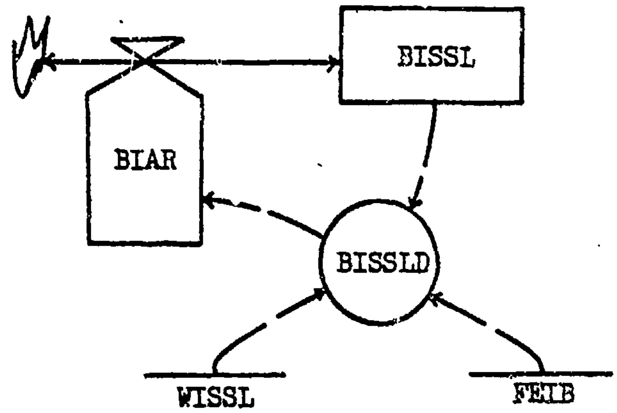



Figure 2-2. Flow Diagram Symbology (3:82-84)

that constitute industrial activity. Five of these represent materials, orders, money, capital equipment, and personnel. The sixth, the information network, is the connecting tissue that interrelates the other five [3: 67].

The flow diagram corresponding to the example causal-loop diagram in Figure 2-1 is presented in Figure 2-3.




```
0025NOTE    BISSL   -BASE ISSL
0050NOTE    BISSLD  -BASE ISSL DISCREPANCY
0075NOTE    BIAR    -BASE ISSL ADJUSTMENT RATE
0100NOTE    WISSL   -WORLDWIDE ISSL
0125NOTE    FEIB    -FRACTION OF END ITEMS ON BASE
```

Figure 2-3. Example Flow Diagram

The primary flow in this diagram is the flow of information concerning the level of the Base ISSL. This flow is represented in the diagram as originating at a source/sink and moving through a two-way "valve" (Base ISSL Adjustment Rate) into the level "Base ISSL". The valve is controlled by the Base ISSL Discrepancy which, in turn, is a function of other factors that are determined by management decisions. According to Figure 2-3 the Base ISSL Adjustment Rate is controlled by an information feedback loop which compares the actual Base ISSL level with the desired Base ISSL level (i.e., the Worldwide ISSL times the Fraction of End Items on Base) to determine if a discrepancy exists. If a discrepancy does exist, the Base ISSL Adjustment Rate is adjusted to correct the discrepancy. From this flow diagram it is possible to construct the mathematical equations that are required to run the model on the computer.

## Equation Formulation

The computer language that is used to implement a system dynamics model is called DYNAMO (10:1). This section discusses the format of the equations used by the DYNAMO program and illustrates the correlation between a flow diagram and its DYNAMO equations. The equations that correspond to the example flow diagram of Figure 2-3 are presented in the text as they are discussed.

Forrester stated that

> The equations tell how to generate the system conditions for a new point in time, given the conditions known from the previous point in time. The equations of the model are evaluated repeatedly to generate a sequence of steps equally spaced in time. Level equations and rate equations generate the levels and rates of the basic model structure. In addition, auxiliary, supplementary, and initial-value equations are used [3: 73].

Before the five classes of DYNAMO equations listed by Forrester can be discussed, it is necessary to explain the time sequence that the DYNAMO program uses as a basis for its computations.

DYNAMO deals with only three times: the present time (K), the time that is one time-unit (DT) in the past (J), and the time that is one time-unit in the future (L). The time-unit, DT, is a constant that is determined by the analyst. Since the program deals with only three points in time (J,K,L), each separated by the time period DT, there are only two time periods in the model: JK and KL, each of which is DT long. When the program is run, the computer calculates all levels at time K and all rates for the time interval KL. The computer then "indexes" time one step into the future (3: 74-75).

> The K levels just calculated are relabeled as J levels. The KL rates become JK rates. Time K, "the present," is thus advanced by one interval of time of DT length. The entire computation sequence can then be repeated to obtain a new state of the system at a time that is one DT later than the previous state [3: 75].

This concept is illustrated graphically in Figure 2-4 and is the basis for the formulation of the five classes of DYNAMO equations.

Level (L) equations define ". . . the varying contents of the reservoirs (stocks, inventories, balances) of the system [3: 76]". Levels would exist even if the system were brought to rest and no flows existed. Level equations are independent of each other and depend only on information before time K (3: 76).

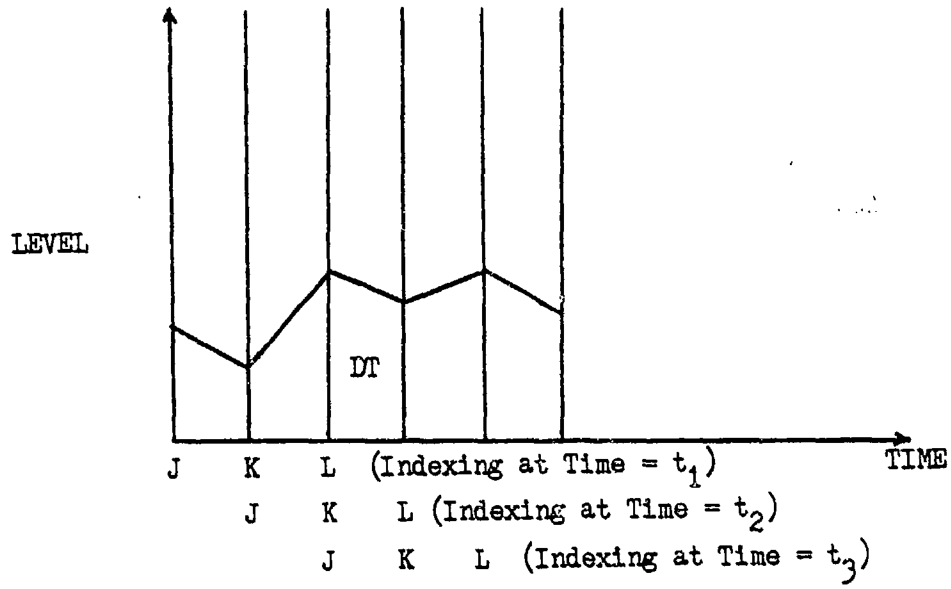



Figure 2-4. DYNAMO Time Flow

An example of a level equation from Figure 2-3 is:

$$BISSL.K = BISSL.J + (DT)(BIAR.JK)$$

This equation states that the present value of the Base ISSL at time K equals the previous value of the Base ISSL computed at time J plus the value of the Base ISSL Adjustment Rate during the last time interval JK times the length of the time interval JK; i.e., DT.

Rate (R) equations define the rate of flow between the levels of the system. They are decision functions of the system and are evaluated from the presently existing values in the levels in the system (3:77). An example of a rate equation from Figure 2-3 is BIAR.KL = BISSLD.K. This equation states that the Base ISSL Adjustment Rate for the time period KL will equal the Base ISSL Discrepancy calculated at time K.

Auxiliary (A) equations are subdivisions of rate equations that permit keeping rate equations simple and in close correspondence with the flow diagram. Examples of auxiliary equations and their corresponding rate equation from another portion of the ISSL development model are:

$$
\begin{aligned}
&\text{A WIARF1.K} = (\text{WID1.K})(\text{WTF1.K})(\text{WTF3.K})/\text{DT} \\
&\text{A WIARF2.K} = (\text{WID2.K})(\text{WTF2.K})(\text{WTF3.K})/\text{DT} \\
&\text{R WIAR.KL} \;\;= (\text{WIARF1.K} + \text{WIARF2.K})
\end{aligned}
$$

Note that all three equations are composed of relatively simple mathematical terms which can be easily related to the structure of a flow diagram. If the three equations are combined into a single rate equation, the expression on the right side of the equation becomes unnecessarily complex:

$$\text{R} \quad \text{WIAR.KL} = \frac{(\text{WTF3.K})((\text{WID1.K})(\text{WTF1.K}) + (\text{WID2.K})(\text{WTF2.K}))}{\text{DT}}$$

Supplementary (S) equations may be used to define variables which are not a part of the structure but which are of interest to the researcher (3:79). They are not used in the ISSL model.

Initial-value (N) equations are used to define the initial values of all levels, and some rates, that must be given before the first cycle of computations can begin (3:79). BISSL = BISSLI is an initial value equation which states that Base ISSL equals the initial Base ISSL.

The five classes of equations discussed in this section are the basic elements of a system dynamics model which can be run on the computer with the DYNAMO simulation language. Forrester issued a word of caution concerning the DYNAMO equations. He stated that

> . . . these equations are not "right" in any intrinsic or mathematical way. They merely describe what we have chosen as the most significant relationships. The equations are akin to a verbal description of the situation. They are wrong to the extent that we wrongly interpret the organization which is being described [3-141].

The "rightness" of the equations will influence the remaining steps of the system dynamics modelling process. These steps are discussed in the next section.

Model Operation, Validation, and Experimentation

Once the three processes of causal-loop diagramming, flow diagramming, and equation formulation were completed for the ISSL development process, the following three steps in the application of system dynamics were accomplished:

> *Generate the behavior through time of the system as described by the model [in this case using the DYNAMO computer program].
>
> . . .
>
> *Compare results against . . . pertinent available knowledge about the actual system.
>
> *Revised the model until it is acceptable as a representation of the actual system [3:13].

Model building is an experimental process. Once the basic model was developed, simulations on the computer were made. The behavior of the model was compared with expected behavior and with the behavior of the actual system. If differences existed, changes in the flow diagrams, the equations, or both were made, and the simulation was reaccomplished. This process was repeated until the behavior of the model closely resembled the behavior of the real world ISSL development process. In this way the internal validity of the model was confirmed. The model was developed to the point where it now can be used as a management laboratory in which the analyst can experiment. It cannot predict the specific state of the system at a given point in the future, but it can show the effects of a change in policy or structure on the general behavior of the system. The ultimate goal of the analyst, and the purpose of the model, is to show the manager of the system how to improve the organization's policies and structure (3:130-133).

## Data Sources

Data necessary for the construction of the causal loop diagrams, flow diagrams, and DYNAMO equations were obtained from AFLC Headquarters personnel through personal interviews and from various DOD, USAF, and AFLC publications. These sources represent the ISSL policy makers and the directives which implement their policy. Specific numerical data were obtained from actual AFLC forms where they were available; where actual data was not available, numbers were intuitively developed to enable the model to operate. Reference to specific data sources are made throughout the following chapters. Statistical techniques were not required in the development of the model.

This completes the discussion of the research methodology. Chapter III identifies the variables in the ISSL development process and discusses the cause and effect relationships among these variables.

# Chapter III

## CAUSE AND EFFECT RELATIONSHIPS

### Introduction

As indicated in Chapter II, the identification of the important variables and their interrelationships begins with a causal-loop diagram of the system under study. This chapter identifies the cause and effect relationships that exist between the variables that interact to form the initial spares support list (ISSL) development process. Goodman stated the purpose of the causal-loop diagram when he said, ". . . causal-loop diagrams allow the analyst to quickly communicate the structual assumptions underlying his model [4:5]."

The causal-loop diagram describes the feedback mechanisms that exist between the variables which make up the system. In order to construct a causal-loop ". . . we must first establish the pairwise relationships of relevant variables [4:5-6]." After the pairwise relationships are established the variables are then ". . . linked together to form the feedback loops of the system. . . [4:11-12]." This process is repeated until all the relevant variables and relationships have been identified and linked together to form the causal-loop diagram of the system under study.

To facilitate the construction of the causal-loop diagram of ISSL development, the process was divided into sectors so that the interacting variables could be more readily identified. Through the use of sectors functions and control processes were grouped into homogeneous areas which made the determination of variable interaction somewhat easier to follow. The sectors that were identified and pursued during the research effort were the initial spares support list (ISSL) Development, Base Inventory, Depot Inventory, and Consumption Sectors. These sectors are interdependent, and their interdependence results in the ISSL development process.

The remainder of this chapter describes each of the individual sectors as they were conceptualized. Each of the sector descriptions includes its causal-loop diagram, an explanation of the pairwise relationships that exists between the variables in that sector, and a discussion of the logic that was used in designing each sector. As the reader progresses through this chapter, the interrelationships of the variables within a given sector and the interrelationship between the sectors should become evident.

Initial Computation Parameters

Selection of items for inclusion on the initial spares support list (ISSL) is ". . . accomplished by the ALC [Air Logistics Center] having support responsibility for the weapon system or end article of equipment [15:12-30]." It is during the initial provisioning conference that the technical equipment specialist, item manager, system manager, contractor, and using command representatives meet to discuss the range and depth of items to be included on the ISSL. However, it is the technical equipment specialist who has ". . . final responsibility for determining the range of items selected for an ISSL [15:12-30]," because he ". . . holds a key role in developing and maintaining logistics support for Air Force systems and equipment [14:1]." The equipment specialist's responsibilities commence ". . . during the conceptual phase of system or equipment development and continues until the system or equipment is removed from the inventory [14:1]."

Among the important functions performed by the equipment specialist are the determination of the reparability of items, the assignment of source, maintenance, and recoverability codes, and the establishment of factors to be used for the maintenance and overhaul of Air Force spare and repair parts. With the maintenance and overhaul factors the equipment specialist is projecting the initial maintenance requirements. These factors are important because they ". . . establish the base line for initial requirements computation [14:6]." The equipment specialist must accurately assign the maintenance and overhaul factors because:

> The accuracy of these factors is reflected in excess or shortages during the initial operational and maintenance support periods. In effect, the maintenance and overhaul factors predicate the total quantitative procurement, asset distribution, dollars spent for spares and repair parts support. . . [14:6].

With the computation parameters set by the equipment specialist the initial requirements computations can begin with the rates and factors furnished to AFLC/LOR on the Programming Checklist.

ISSL Development Sector

The causal-loop diagram of the inital spares support list (ISSL) development sector is presented as Figure 3-1.

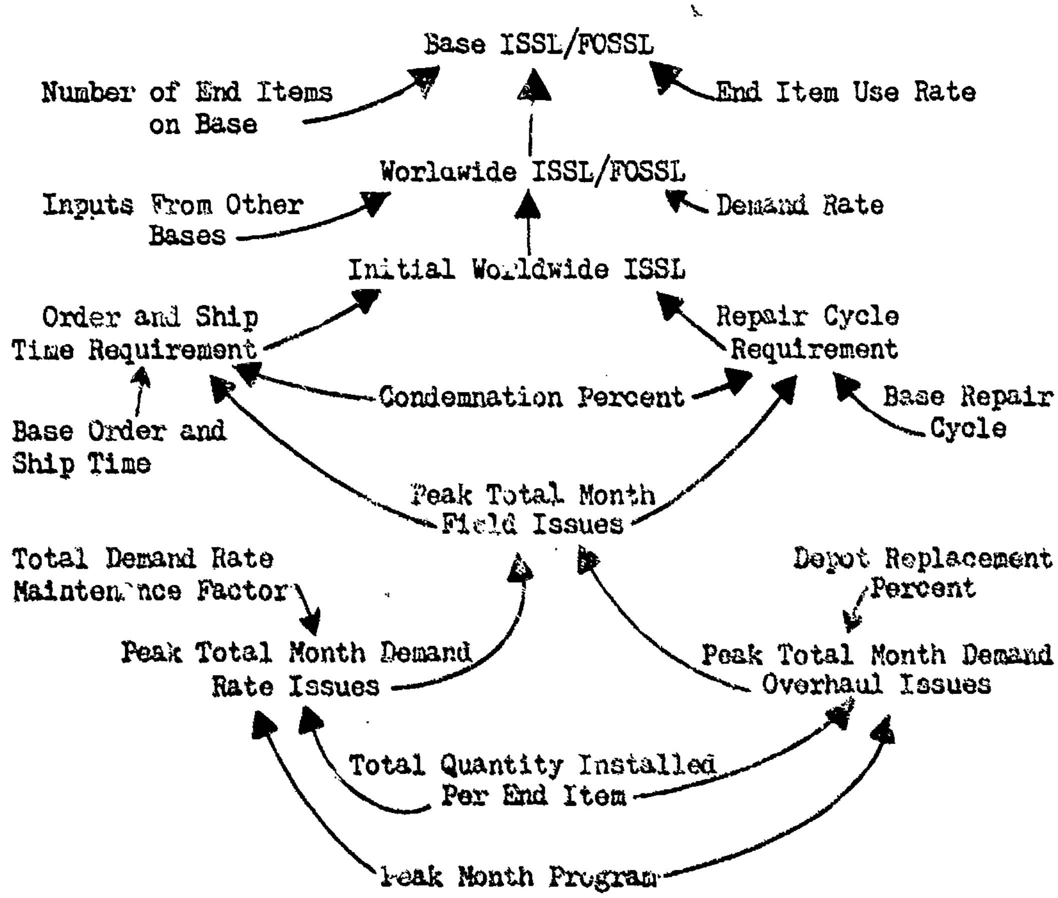



Figure 3-1. ISSL Development Sector Causal-Loop

The input variables to this sector are the initial computation parameters furnished to the Directorate of Materiel Requirements in Headquarters, Air Force Logistics command (AFLC/LOR) by the equipment specialist on the Programming Checklist (14:6-11). Using these parameters the initial requirements for the economic order quantity items ". . . which have been identified as logical spares and/or repair parts during initial provisioning. . . [12:2-1]" can be determined. AFLC Form 997, EOQ Initial Provisioning Worksheet, is normally ". . . used to manually determine initial EOQ spares/repair parts requirements for centrally procured items coded for Air Force management . . . [12:2-1]." The variables which form this sector were derived from the computation worksheet.

In Figure 3-2 are shown the relationships that exist between the Peak Month Program (projected monthly demand), Total Quantity Installed per End Item, and Total Demand Rate Maintenance Factor parameters from the Programming Check List on the Peak Total Month Demand Rate Issues (projected repair requirements) variable on the provisioning worksheet. The positive polarity of the Peak Month Program, Total Quantity Installed per End Item, and on the Total Demand Rate Maintenance Factor parameters indicate that as either one of these parameters increase there will also be an increase in the Peak Total Month Demand Rate Issues variables.

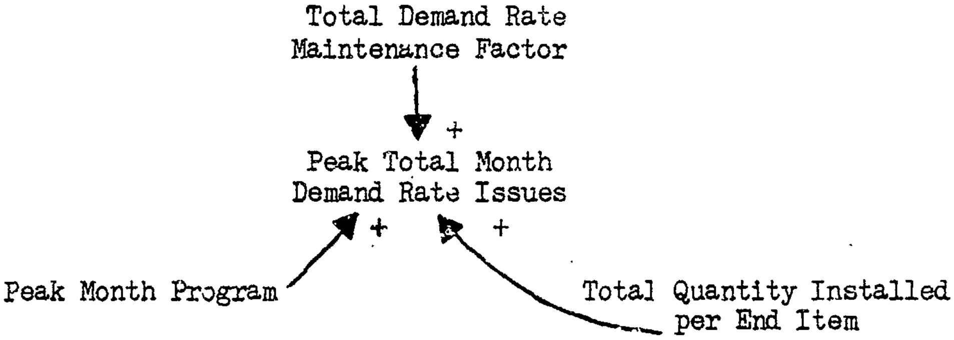



Figure 3-2. Peak Total Month Demand Rate Issues Causal-Loop

Figure 3-3 shows the relationship and polarity that exists between the same Peak Month Program and Total Quantity Installed per End Item parameters, and the Depot Replacement Percent parameter which is ". . . developed from the overhaul replacement factor or the provisioning document [12:2-2]," with the Peak Total Month Demand Overhaul Issues (projected depot level issues for repairs). As indicated in the causal-loop diagram for this portion of the sector all three of the parameters have a positive effect on the computation of the requirement variable which means that as the parameters increase so will the calculated variable value (12:2-2,3).

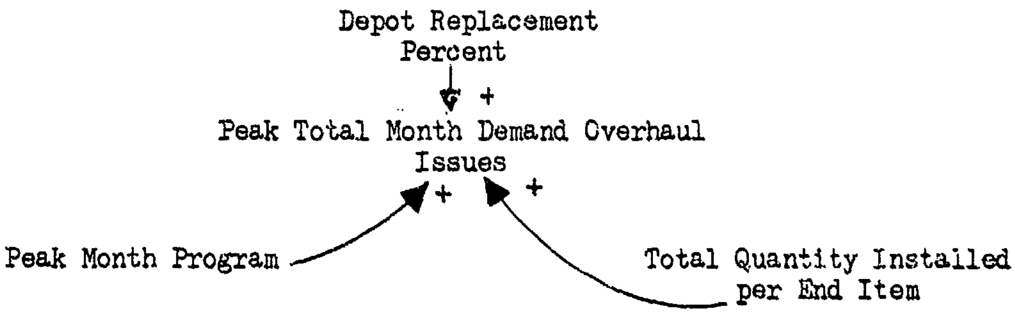



Figure 3-3. Peak Total Month Demand Overhaul Issues Causal-Loop

The calculated values for the Peak Total Month Demand Rate Issues and Peak Total Month Demand Overhaul Issues have an impact on the provisioning worksheet value for the variable Peak Total Month Field Issues (projected base level issues for repairs). The interrelationship of the calculated variables is indicated in Figure 3-4. As the Peak Total Month Demand Rate Issues increase so will the Peak Total Month Field Issues; however, as the Peak Total Month Demand Overhaul Issues increase there is a decrease in the Peak Total Month Field Issues (12:2-3).

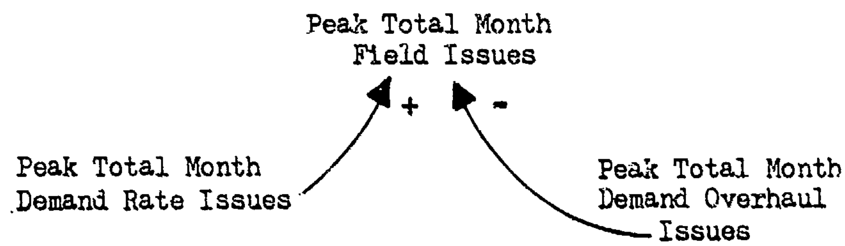



Figure 3-4. Peak Total Month Field Issues Causal-Loop

The Peak Total Month Field Issues interacts with standard support times used for Base Order and Ship Time, Base Repair Cycle, and Condemnation Percent to determine the Order and Ship Time Requirement and the Repair Cycle Requirement. Since ". . . initial spares procurement will be limited to new items [12:1-1]," standard support times are used because ". . . no actual data is available [12:2-1]."

The Order and Ship Time Requirement causal-loop is presented as Figure 3-5. Each of the variables involved, Peak Total Month

Field Issues, Base Order and Ship Time, and Condemnation Percent, have a positive effect on the Order and Ship Time Requirement. The result of these positive effects is that as either of variables increase so will the Order and Ship Time Requirement.

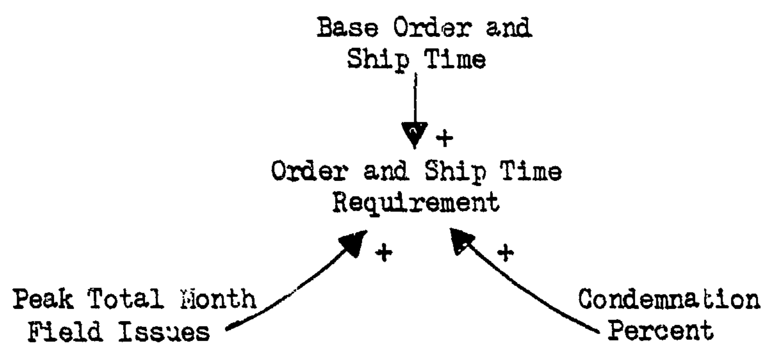



Figure 3-5. Order and Ship Time Requirement Causal-Loop

Figure 3-6 depicts the interrelationships that exist to form the Repair Cycle Requirement. In this instance the Peak Total Month Field Issues and the standard value for the Base Repair Cycle have a positive effect on the Repair Cycle Requirement. Therefore, as these variables increase so will the Repair Cycle Requirement increase. However, the Condemnation Percent has a negative effect which means that as the Condemnation Percent increases the Repair Cycle Requirement will decrease. The Condemnation Percent for EOQ items ". . . will always equal 1.00 [12:2-2];" thus, the Repair Cycle requirement is zero for EOQ items. This will be explained further in Chapter IV.

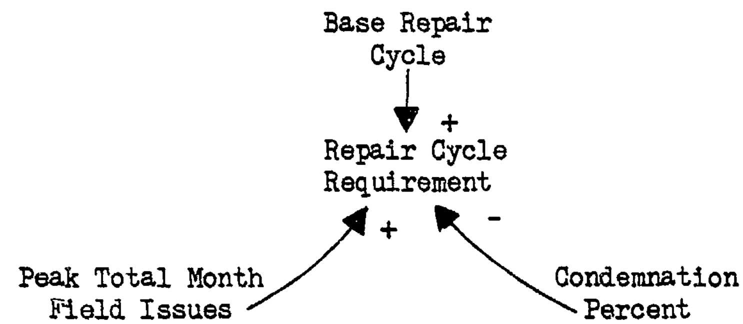



Figure 3-6. Repair Cycle Requirement Causal-Loop.

The Order and Ship Time Requirement and Repair Cycle Requirement interact as shown in Figure 3-7 on the Initial Worldwide ISSL. Both of the calculated variables have a positive effect on the ISSL. As the Order and Ship Time Requirement or Repair Cycle Requirement increases the Initial Worldwide ISSL will also increase.

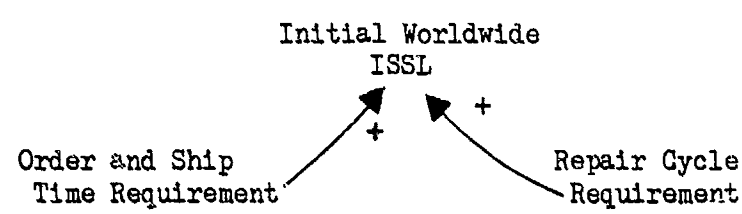



Figure 3-7. Initial Worldwide ISSL Causal-Loop.

In order to show the effects of adjustments made to the initial ISSL quantities as the system progresses through time, a new variable called Worldwide ISSL was introduced. The Worldwide ISSL variable differs from the Initial Worldwide ISSL because it takes into consideration the experience gained at those bases that have used the initial ISSL quantities in support of the weapon system/equipment activation. In addition, the worksheets with the original computations ". . . must be available for HQ AFLC review during regularly scheduled materiel management reviews [12:2-1]." The interactions of the variables that have an impact on Worldwide ISSL are shown in Figure 3-8. It should be noted that if the ISSL is still in its initial stages of deployment and actual experiences are limited the Initial Worldwide ISSL and the Worldwide ISSL are the same.

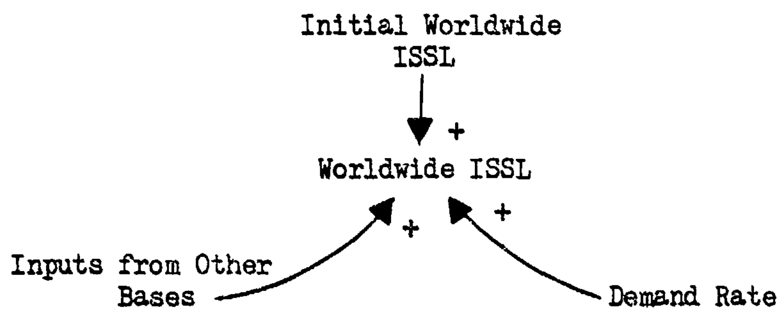



Figure 3-8. Worldwide ISSL Causal-Loop

As shown in Figure 3-8, as the Inputs From Other Bases goes up there will be an increase in the Worldwide ISSL. Similarly, as the Demand Rate experienced from actual usage of the ISSL goes up there will again be an increase in the Worldwide ISSL. As the Initial Worldwide ISSL goes up, so too will the Worldwide ISSL because they are essentially the same, differeing only in time; i.e., the Initial Worldwide ISSL initializes the Worldwide ISSL to a given value, after which time the Worldwide ISSL becomes a function of actual consumption data.

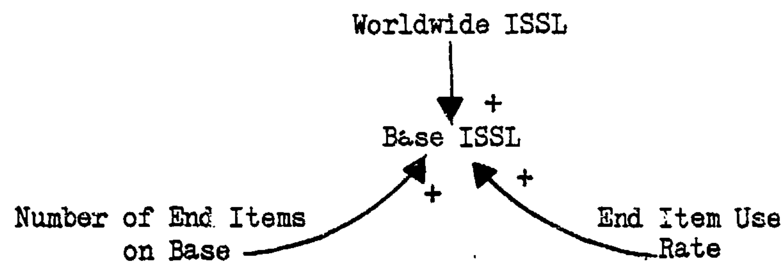



Figure 3-9. Base ISSL Causal-Loop

The Base ISSL causal-loop diagram, Figure 3-9, is the final portion of the ISSL development sector. As the Worldwide ISSL increases the Base ISSL will also increase. Further, either the Number of End Items On Base or the Base End Item Use Rate will have a positive effect on the Base ISSL. This is true because as the number of end items increase or the more the end item is used, the greater the amount of spare/replacement parts will be required to support the end item (11).

Thus, the ISSL Development Sector is composed of several interdependent causal-loops which interact to produce the quantity of items required to provide the projected end item support. The description of Base ISSL causal-loop provides a point to begin the description of the Base Inventory Sector.

## Base Inventory Sector

The Base initial spares support list (ISSL) is the connecting link between the ISSL Development Sector and the Base Inventory Sector as shown in Figure 3-10. The reader should note that the

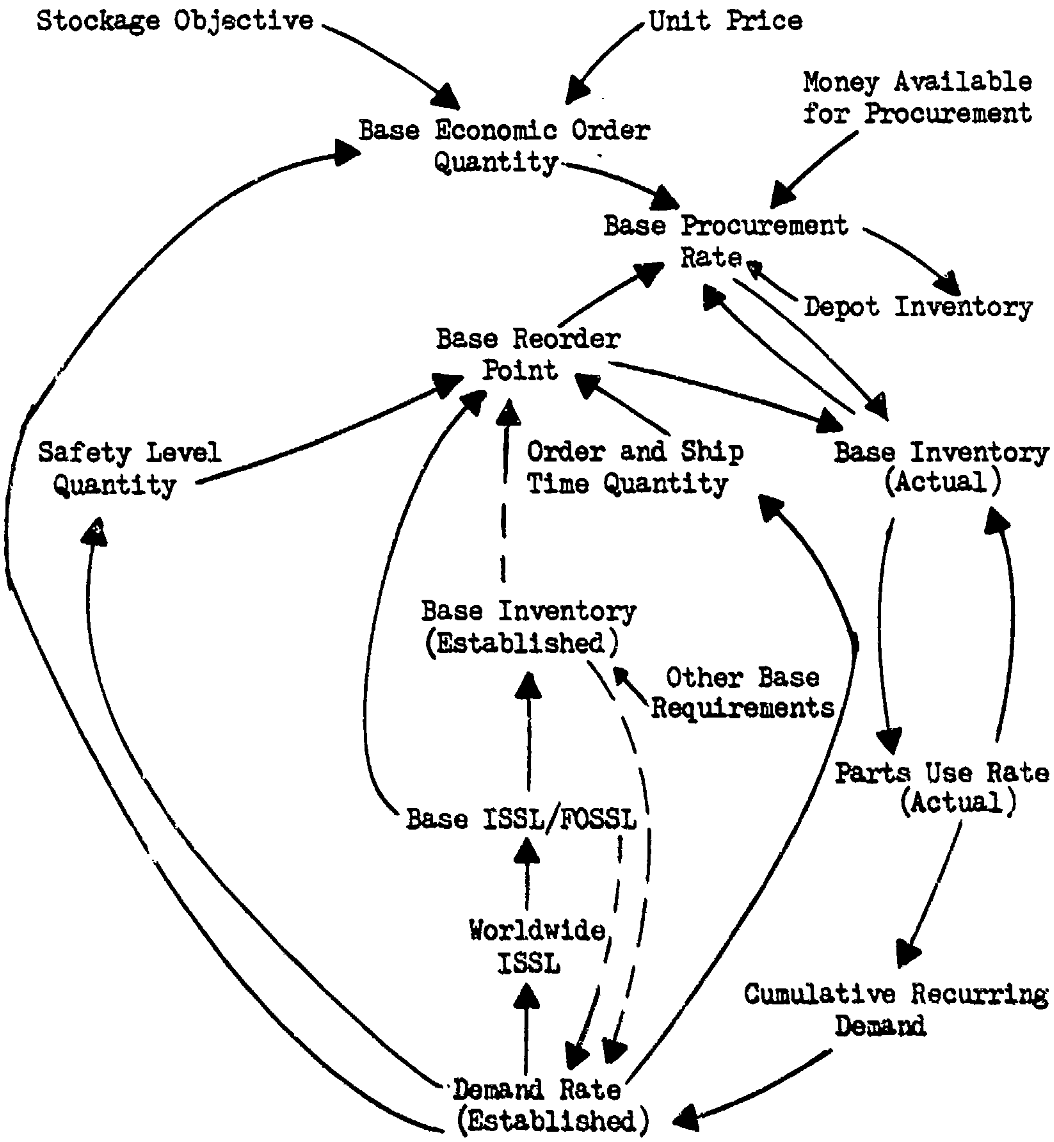



Figure 3-10. Base Inventory Sector Causal-Loop

Demand Rate element is not only in the ISSL development but also in the Base Inventory Sector as well. The Demand Rate is used to calculate the Safety Level Quantity, the Order and Ship Time Quantity and the Economic Order Quantity in this Sector.

Figure 3-11 shows that as the Demand Rate goes up the Safety Level Quantity also increases. Similarly, as the Demand Rate increases, the Order and Ship Time Quantity also increase. It should be noted that a Safety Level Quantity is utilized only if the calculated safety level is greater than the demand rate multiplied by fifteen; otherwise, the Safety Level Quantity is equal to the demand rate multiplied by fifteen (17:11-13).


Figure 3-11. Safety Level Quantity and Order and Ship Time Quantity Causal-Loop

After calculating the Safety Level Quantity and the Order and Ship Time Quantity, the Base Reorder Point can be determined. The causal-loop diagram for the Base Reorder Point, Figure 3-12, reveals that the Safety Level Quantity and the Order and Ship Time Quantity each have a positive effect on the Base Reorder Point such that as either one goes up so too will the Base Reorder Point. In addition to these two variables, the Base ISSL also has a positive effect on the Base Reorder Point which means that as the Base ISSL quantity increases the Base Reorder Point will also go up.

The Base Inventory level established by the Base ISSL receives a positive impact from not only the Base ISSL but also from Other Base Requirements as well (Figure 3-12). The established Base Inventory has an impact on the Base Reorder Point in providing a timing factor, as the reorder point used by the base is ". . . 1/3 the minimum level quantity (ISSL) or normal reorder point whichever is greater [17:11-53]." The ISSL represents the minimum level of a given item that must be on hand or on order, or a combination of the two, in order to provide adequate system support as determined by the equipment specialist (6,8,11).

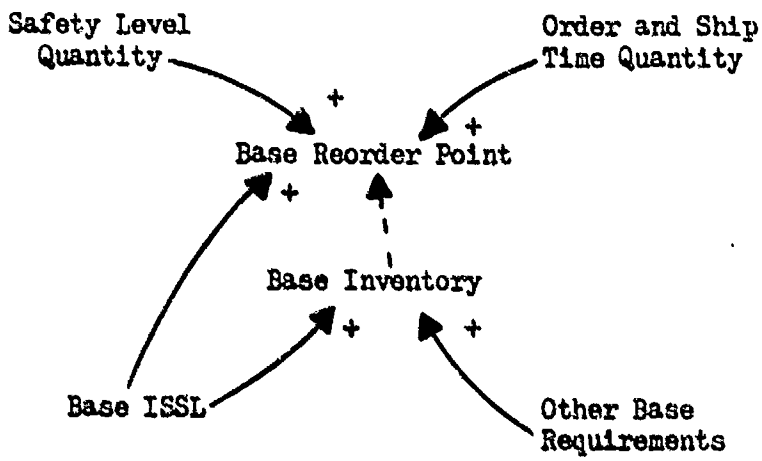



Figure 3-12. Base Reorder Point Causal-Loop

The Demand Rate variable also interacts with the Variable Stockage Objective and Unit Price in the Base Economic Order Quantity causal-loop (Figure 3-13). As the Demand Rate increases, the Base Economic Order Quantity also increases which indicates a positive effect. The Variable Stockage Objective, which represents the number of days items should be stocked to cover, also has a positive effect on the Base Economic Order Quantity (17:11-6). The Base Economic Order Quantity receives a negative effect from the Unit Price because as the Unit Price increases the Base Economic Order Quantity will have a corresponding decrease.

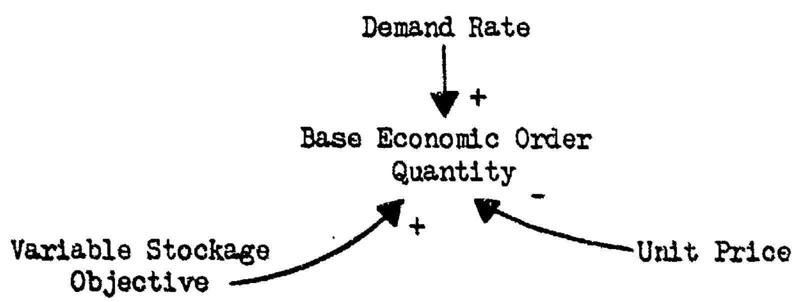



Figure 3-13. Base Economic Order Quantity Causal-Loop

Aside from the Demand Rate, the Base Reorder Point also plays an important role in the Base Inventory Sector. The Base Reorder Point is an important factor in the Base Procurement Rate causal-loop, and the actual Base Inventory causal-loop diagrams.

The Base Procurement Rate receives positive inputs from the Base Reorder Point, Base Economic Order Quantity, and from the Money

Available for Procurement (Figure 3-14). As any one of these variables increases the Base Procurement Rate will also increase. The point should be made that while a variable for Money Available for Procurement was included in the Base Procurement Rate it was done so only as a matter of completeness. The Money Available for Procurement variable represents an exogenous system to the ISSL development process and was not thoroughly researched. The inventory specialists interviewed indicated that once a requirement for additional operating and maintenance funds were made known to the Base Financial Activity, funds were made available to purchase the required items (6,8,11).

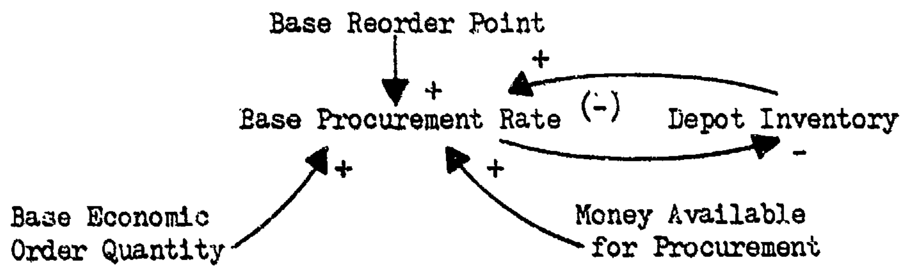



Figure 3-14. Base Procurement Rate Causal-Loop

Also depicted in Figure 3-14 is the positive effect of the Depot Inventory on the Base Procurement Rate while the Base Procurement Rate has a negative impact on the Depot Inventory. The reason for this dichotomy should be intuitive in that as the Depot Inventory has the required items, the Base is able to procure them which, in turn, reduces the Depot Inventory. Another variable which has a dual impact on the Base Procurement Rate is the actual Base Inventory (Figure 3-15).

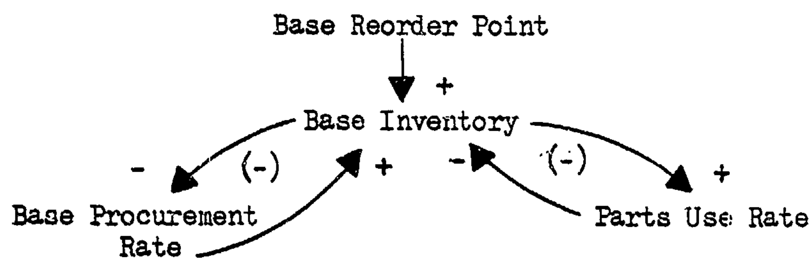



Figure 3-15. Base Inventory Causal-Loop

As the actual Base Inventory increases the Base Procurement Rate will decrease; conversely, as the Base Procurement Rate increases the actual Base Inventory will also increase. Also shown in Figure 3-15 is the positive effect of the Base Reorder Point on actual Base Inventory. This indicates that as the Base Reorder Point goes up, the actual Base Inventory will also increase.

Before completing a description of this sector a discussion of how the Base Inventory Sector is interdependent on the Consumption Sector and how it provides a means of updating other Base ISSLs is warranted. The Parts Use Rate Variable connects the Base Inventory Sector directly to the Consumption Sector as will be discussed later in this chapter, and indirectly connects the Base Inventory Sector with the Worldwide ISSL through the Demand Rate.

As indicated in Figure 3-15, the Base Inventory has a positive impact on the actual Parts Use Rate which in turn has a negative impact on the actual Base Inventory. This means that as the actual Base Inventory increases the actual Parts Use Rate can also increase; on the other hand as the Parts Use Rate increases the Base Inventory decreases.

Figure 3-16 shows that as the Parts Use Rate goes up the Cumulative Recurring Demand also goes up. The Cumulative Recurring Demand represents the accumulated total of parts used over a given period of time. Also shown by Figure 3-16 is that as the Cumulative Recurring Demand increases the Demand Rate will also increase due to the positive impact of Cumulative Recurring Demand on the established Demand Rate.

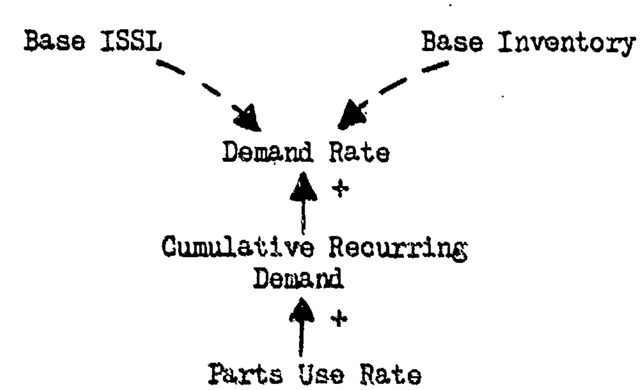



Figure 3-16. Demand Rate Causal-Loop

If the Demand Rate changes by a significant amount the Base ISSL and the established Base Inventory level must be considered in determining if a change in quantity is warranted. However, ". . . demand levels will be changed only when the amount of change equals or exceeds the square root of the existing level [17:11-4]."

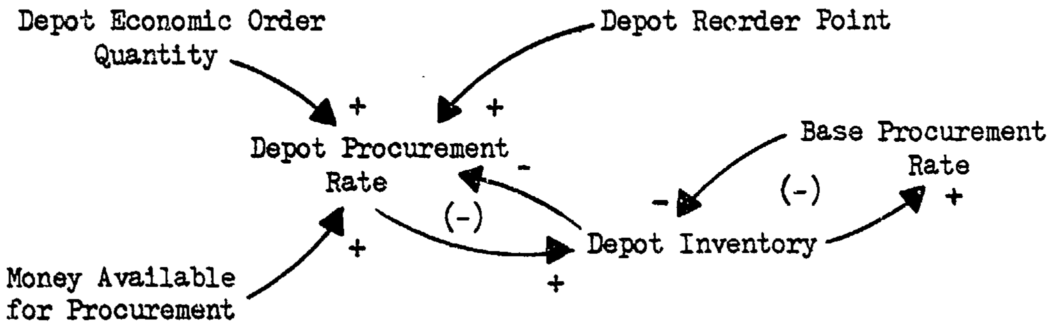



Figure 3-17. Depot Inventory Sector Causal-Loop

Depot Inventory Sector

The Depot Inventory causal-loop diagram (Figure 3-17) is interdependent with the Base Inventory Sector through the Base Procurement Rate as discussed in the Base Inventory Sector description. As was the case with the Base Inventory, the Depot Inventory has a negative effect on the Depot Procurement Rate which in turn has a positive impact on Depot Inventory. As in the similar case, this means that as the Depot Inventory goes up the Depot Procurement Rate goes down; conversely, as the Depot Procurement Rate increases the Depot Inventory also increases.

Figure 3-17 also shows that the Depot Procurement Rate is positively correlated to the Depot Economic Order Quantity, Depot Reorder Point, and Money Available for Procurement. However, since the depot inventory system is exogenous to the initial spares support list (ISSL) development process it was not thoroughly researched; research was conducted only to the extent to determine the effects

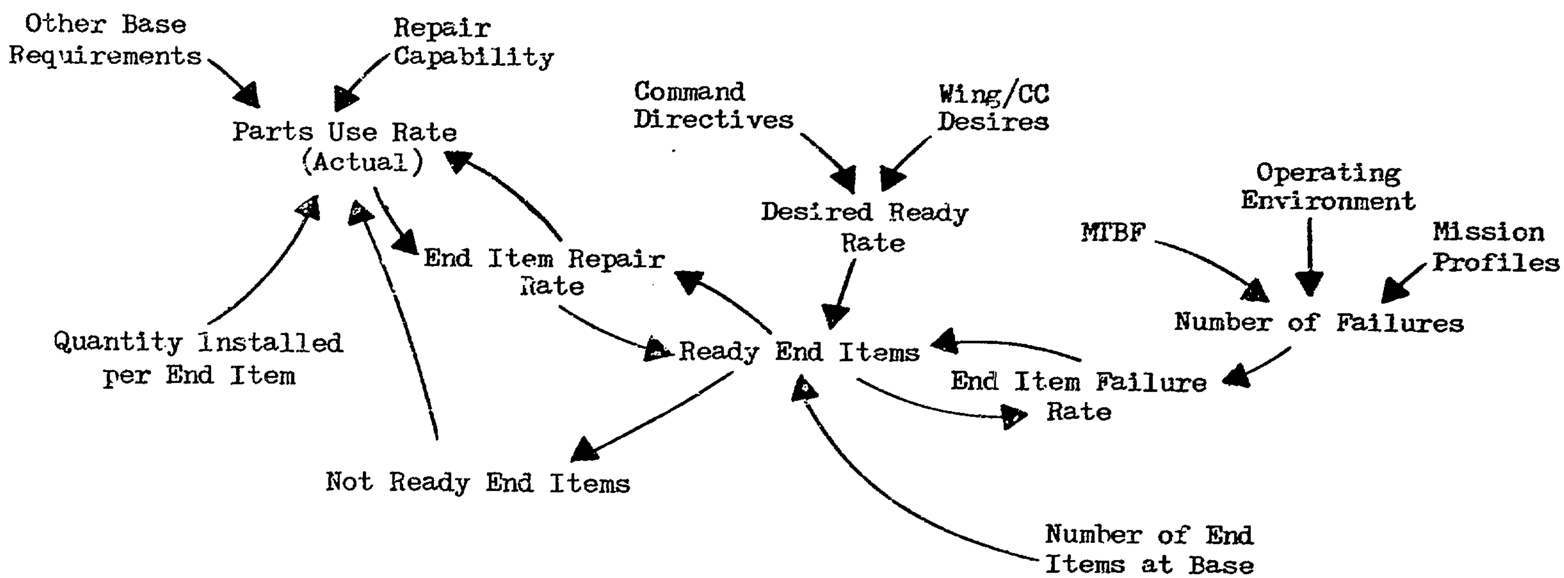



Figure 3-18. Consumption Sector Causal-Loop

of the Depot Inventory System on the Base inventory system. Thus, only the essential variables have been included.

## Consumption Sector

The causal-loop diagram of the Consumption Sector is presented as Figure 3-18. One of the key elements of this sector is the Parts Use Rate. The Parts Use Rate variable represents the withdrawal of spare/replacement items from the Base inventory. The rate which the parts are removed is affected by the number of Not Ready End Items, the Quantity of item Installed per End Item, the Repair Capability, and Other Base Requirements for the items, if any exist. Figure 3-19 shows the relationship that exists between these variables and the Parts Use Rate.

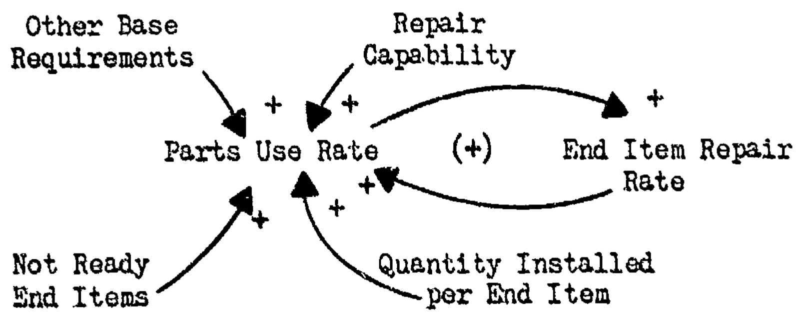



Figure 3-19. Parts Use Rate Causal-Loop

As indicated by the assigned polarity symbols, each of the variables have a positive impact on the Parts Use Rate such that as either of the variables increase there will also be a corresponding increase in the Parts Use Rate. Note also that the End Item Repair

Rate has a positive impact on the Parts Use Rate which in turn has a positive impact on the End Item Repair Rate. This means that as either the End Item Repair Rate or the Parts Use Rate increases there will be an increase in the other variable.

The End Item Repair Rate is also a factor that affects the number of Ready End Items on the Base to carry out the assigned mission (Figure 3-20). As the End Item Repair Rate goes up the number of Ready End Items will also increase. Conversely, it is intuitive that as the Ready End Items increase the End Item Repair Rate will go down because there are fewer Not Ready End Items.

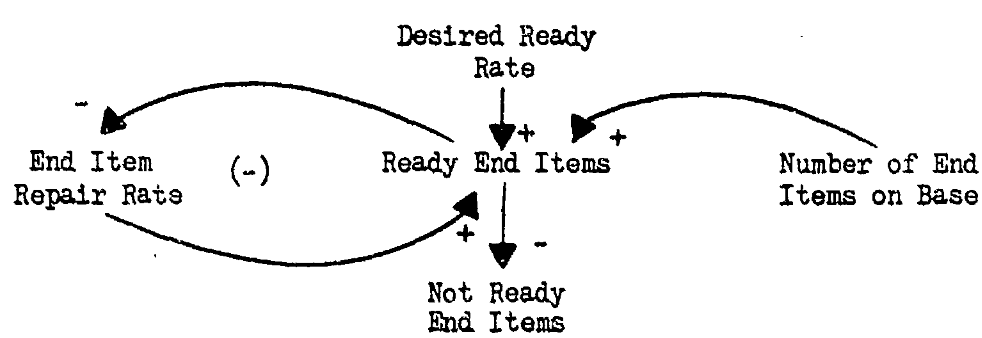



Figure 3-20. Ready End Items Causal-Loop

The concept of fewer Not Ready End Items is also illustrated in Figure 3-20 by the negative polarity given to the relationship that exists between the Ready End Items and Not Ready End Items.

Figure 3-20 also shows that the number of Ready End Items is also affected by the Desired Ready Rate and the Number of End Items on Base. Both of these variables have a positive affect on the number of Ready End Items. The Desired Ready Rate is affected by two variables (Figure 3-21).

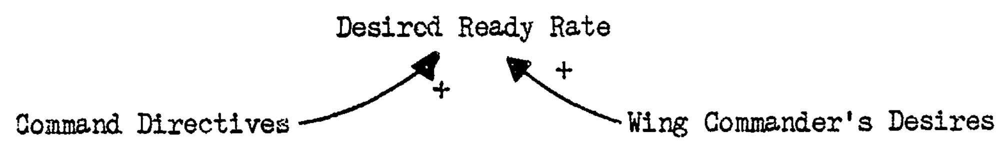



Figure 3-21. Desired Ready Rate Causal-Loop

Command Directives and the Wing Commanders Desires have a positive impact on the Desired Ready Rate. As either one goes up the Desired Ready Rate will also increase. Command Directives represent the percentage of assigned end items which must be ready to meet the assigned Base mission, the Command Directives are oftentimes augmented by the Wing Commander Desires to meet unforeseen emergencies or contingency operations.

Ready End Items is affected by and has an impact on the End Item Failure Rate (Figure 3-22). The number of Ready End Items has a positive relationship with End Item Failure Rate in that as the number of Ready End items increases more failures are expected. On the other side of the coin, as the End Item Failure Rate goes up the number of Ready End Items will decrease. The relationship that exists between the Number of Failures and End Item Failure Rate is also shown in Figure 3-22. As the Number of Failures increase there is also an increase in the End Item Failure Rate.

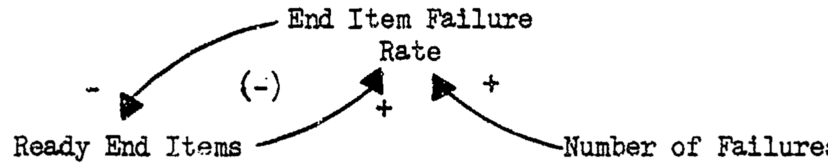



Figure 3-22. End Item Failure Rate Causal-Loop

The final variable conceptualized as being in the Consumption Sector is the Number of Failures. The three variables that interact and affect the Number of Failures are shown in Figure 3-23. All three of the variables, Mean Time Between Failure, Operating Environment, and Mission Profiles, have negative affects on the Number of Failures. This means that as the Mean Time Between Failure increases, or the Operating Environment goes up in terms of being better for end item operation, or the Mission Profile, which is how the item is used, goes up or improves the Number of Failures will decrease. Number of Failures pertains to not only end item failure but to component failure which takes the end item out of mission ready status.

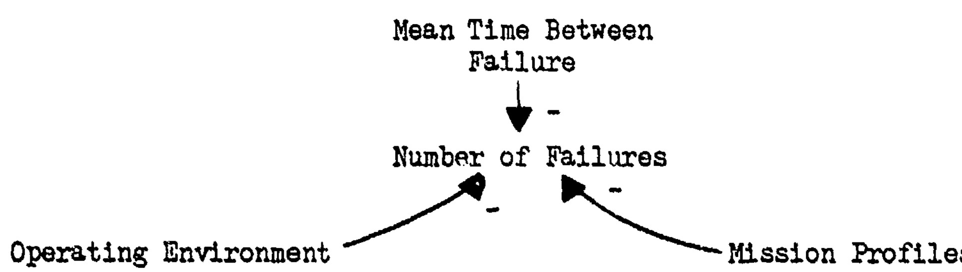



Figure 3-23. Number of Failures Causal-Loop

The four sector causal-loop diagrams can be combined to form a single causal-loop diagram of the initial spares support list (ISSL) development process, and the interaction of the component variables would not change. While the causal-loop diagrams are useful during the conceptualization of a system because ". . . they help identify and organize principal components and feedback loops of the system under study [4:11]." However, flow diagrams are essential in ". . . model construction and equation writing [4:11]," because the causal-loop diagrams ". . . lack the precision and detail of the rate, level, and auxiliary elements found in flow diagrams [4:11]."

The causal-loop diagrams discussed in this chapter formed the basis upon which the flow diagrams of the ISSL development process were devised. The flow diagrams and the mathematical equations of the dynamic ISSL development process model are the subjects of the next chapter.

Chapter IV

# FLOW DIAGRAMS AND DYNAMO EQUATIONS

## Introduction

In this chapter the causal loop diagrams that were presented in Chapter III are transformed into System Dynamics flow diagrams and DYNAMO equations. Each of the four sectors is treated as an individual unit and the connections between the sectors are identified where they occur. In order to simplify explanation of the flow diagrams, they have been divided into small sections. These sections are then presented along with the corresponding DYNAMO equations. The discussion of each sector begins with a central level or auxiliary variable. The sector is then decomposed variable-by-variable until further decomposition is no longer possible; i.e., the discussion reaches a constant or a variable that has either been previously discussed or that will be discussed in another section.

To avoid continuous repetition, three concepts that appear in many of the model's equation are explained here. The first is the concept of an adjustment rate. Chapter II briefly addressed this concept in the discussion of the rate (decision) symbol and the rate equation. An adjustment rate controls the quantity of material or information in its associated level. It may be thought of as a valve that opens or closes to determine how much material or information moves into or out of the level and at what speed (rate).

The adjustment rates are generally influenced by many factors. These adjustment rate factors have been designed to determine the magnitude of the adjustment rate and to establish the timing of the rate; i.e., at what points in time the "valve" opens or closes. These factors have been called various names throughout the system in order to identify their function. Some examples are the Base Fraction Ordered factors 1 through 5, the Worldwide ISSL Adjustment Rate Factor, and the Adjustment Timing Factor. These factors are, in turn, a function of various variables that are identified in the appropriate discussion.

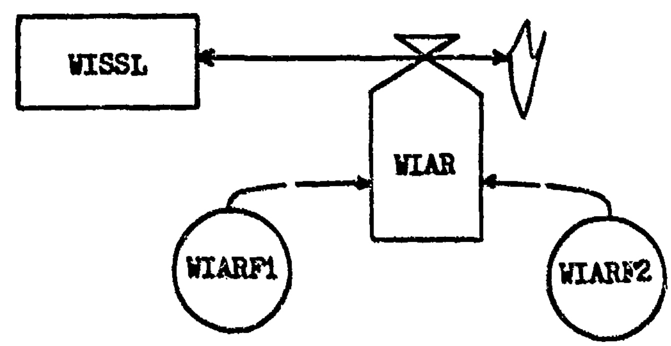
The third concept is that of Delta Time (DT). This variable appears in many equations. Its purpose is to make the model insensitive to the computation interval of the simulation. If the analyst wants a "high resolution" simulation that will indicate the minute variations in the system, he may set the computation interval equal to a day or a fraction of a day; if, on the other hand, he is interested only in the general behavior of the system, he may set the computation interval equal to a week (7 days), a month (30 days), or even a year (365 days). The variable DT automatically adjusts the various rate and auxiliary equations to the computation interval so that the model correctly simulates the operation of the system.

For reference, complete sector flow diagrams and the entire computer program listing are presented in the appendices. The first sector to be discussed is the ISSL Development Sector.

## ISSL Development Sector

This sector describes the process that is involved in the initial development of the ISSL. The process has been divided into two parts: the development of the Worldwide ISSL and the development of the Base level ISSL.

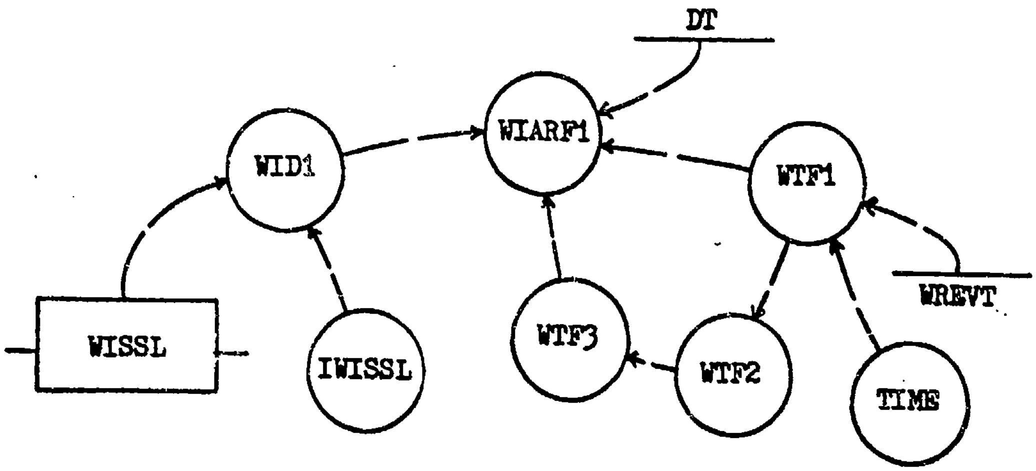
The Worldwide ISSL level is the quantity of a given item that is required per month to support the entire weapon system under study until normal demand rates can be established. Figure 4-1 illustrates that it is a function of the Worldwide ISSL Adjustment Rate. The Worldwide ISSL Adjustment Rate is the sum of two factors: the Worldwide ISSL Adjustment Rate Factor 1 and the Worldwide ISSL Adjustment Rate Factor 2.




```
175L WISSL.K=WISSL.J+(DT)(WIAR.JK)
200NOTE     WISSL   -WORLDWIDE ISSL
225NOTE     DT      -DELTA TIME
250NOTE     WIAR    -WORLDWIDE ISSL ADJUSTMENT RATE
275R WIAR.KL=WIARF1.K+WIARF2.K
300NOTE     WIAR    -WORLDWIDE ISSL ADJUSTMENT RATE
325NOTE     WIARF1  -WORLDWIDE ISSL ADJUSTMENT RATE FACTOR 1
350NOTE     WIARF2  -WORLDWIDE ISSL ADJUSTMENT RATE FACTOR 2
```

Figure 4-1. ISSL Development Sector Diagram 1

Figure 4-2 illustrates that the Worldwide ISSL Adjustment Rate Factor 1 is a function of the Worldwide ISSL Discrepancy 1, the timing factors 1 and 3, and Delta Time. This set of factors forces the computer program to compare the Worldwide ISSL level to the

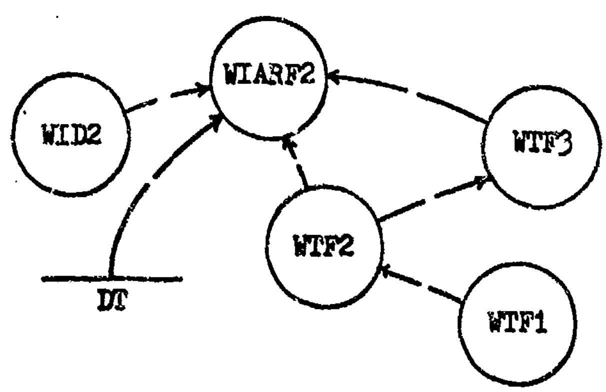



```
375A WIARF1.K=(WID1.K)(WTF1.K)(WTF3.K)(1/DT)
4ØØNOTE      WIARF1  -WORLDWIDE ISSL ADJUSTMENT RATE FACTOR 1
425NOTE      WID1    -WORLDWIDE ISSL DISCREPANCY 1
45ØNOTE      WTF1    -WORLDWIDE ISSL TIMING FACTOR 1
475NOTE      WTF3    -WORLDWIDE ISSL TIMING FACTOR 3
5ØØNOTE      DT      -DELTA TIME
525A WID1.K=IWISSL.K-WISSL.K
55ØNOTE      WID1    -WORLDWIDE ISSL DISCREPANCY 1
575NOTE      IWISSL  -INITIAL WORLDWIDE ISSL
6ØØNOTE      WISSL   -WORLDWIDE ISSL
625A WTF1.K=CLIP(Ø,1,TIME.K,WREVT)
65ØNOTE      WTF1    -WORLDWIDE ISSL TIMING FACTOR 1
675NOTE      TIME    -TIME
7ØØNOTE      WREVT   -WORLDWIDE ISSL REVIEW TIME
725A WTF2.K=CLIP(Ø,1,WTF1.K,Ø.5)
75ØNOTE      WTF2    -WORLDWIDE ISSL TIMING FACTOR 2
775NOTE      WTF1    -WORLDWIDE ISSL TIMING FACTOR 1
8ØØL WTF3.K=CLIP(Ø,1,WTF2.J,Ø.5)
825NOTE      WTF3    -WORLDWIDE ISSL TIMING FACTOR 3
85ØNOTE      WTF2    -WORLDWIDE ISSL TIMING FACTOR 2
```

Figure 4-2. ISSL Development Sector Diagram 2

Initial Worldwide ISSL until the point in time established by the Worldwide ISSL Review Time. In other words, they force the Worldwide ISSL level to equal the Initial Worldwide ISSL until the Worldwide ISSL Review Time is reached. Figure 4-2 also illustrates that the Worldwide ISSL Discrepancy 1 is simply the difference between the current Worldwide ISSL level and the Initial Worldwide ISSL.

The second factor that controls the Worldwide ISSL Adjustment Rate is the Worldwide ISSL Adjustment Rate Factor 2. Figure 4-3 illustrates that it is also a function of four factors: the Worldwide ISSL Discrepancy 2, Timing Factors 2 and 3, and Delta Time.



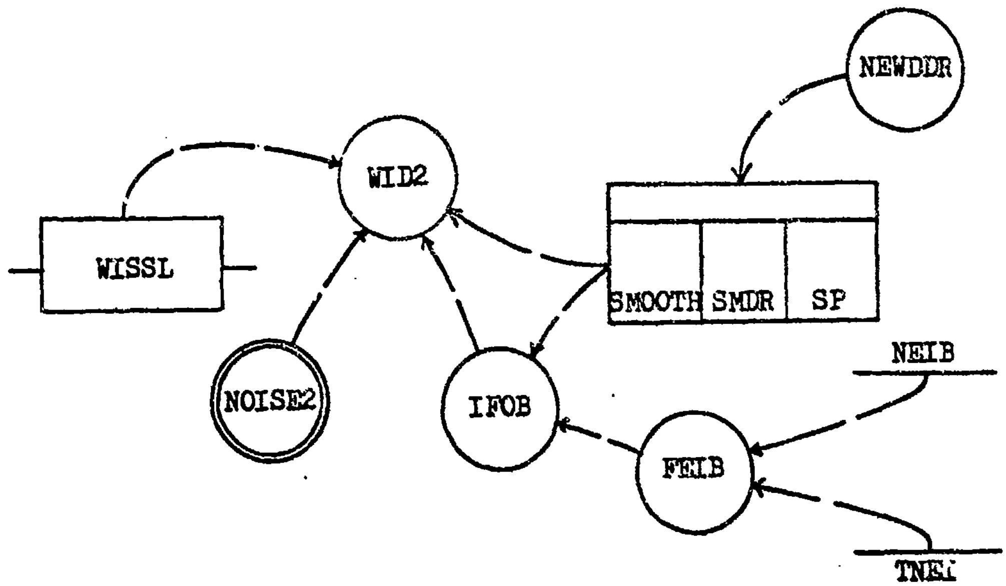

```
875A WIARF2.K=(WID2.K)(WTF2.K)(WTF3.K)(1/DT)
900NOTE      WIARF2  -WORLDWIDE ISSL ADJUSTMENT RATE FACTOR 2
925NOTE      WID2    -WORLDWIDE ISSL DISCREPANCY 2
950NOTE      WTF2    -WORLDWIDE ISSL TIMING FACTOR 2
975NOTE      WTF3    -WORLDWIDE ISSL TIMING FACTOR 3
1000NOTE      DT      -DELTA TIME
```

Figure 4-3. ISSL Development Sector Diagram 3

These factors force the program to compare the Worldwide ISSL level to the Worldwide ISSL Discrepancy 2 at the point in time that is determined by the Worldwide ISSL Review Time. At that time the Worldwide ISSL level is revised if necessary. Since command directives require that ISSL reviews be kept to a minimum, the model was designed to review the Worldwide ISSL only once during each simulation.

The Worldwide ISSL Discrepancy 2 is the difference between the Worldwide ISSL level and the smoothed worldwide total monthly demand rate for the item under study. It is a function of four factors as illustrated in Figure 4-4. The Smoothed Monthly Demand Rate is a function of the actual demand rate for an item that has been established through experience at a single base for the weapon system under study for a period of time that is determined by the Smoothing Period. The Input From Other Bases is estimated from the Smoothed Monthly Demand Rate and the Fraction of End Items at the one Base. The weapon system's total monthly demand rate is calculated and then multiplied by a noise factor to simulate reporting errors (see Chapter I). This figure is then compared to the current Worldwide ISSL level to determine the Worldwide ISSL Discrepancy 2.

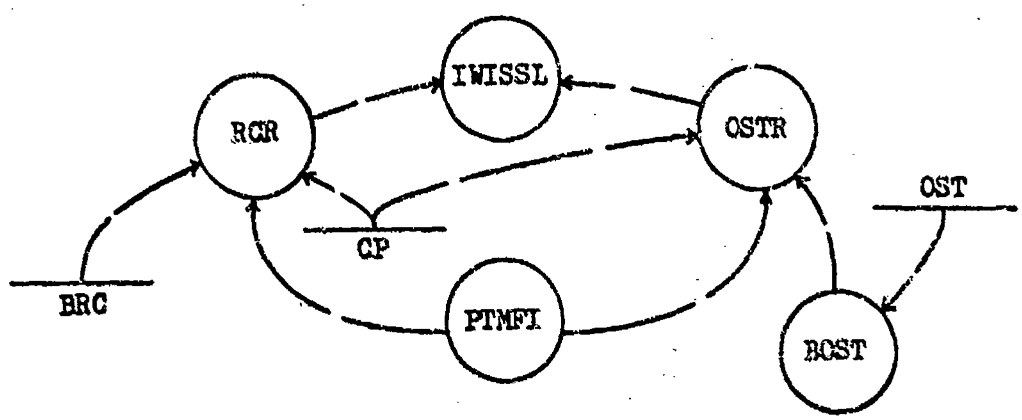
The Initial Worldwide ISSL is the second factor that is used to calculate the Worldwide ISSL Discrepancy (see Figure 4-2). It is the original AFLC estimate of the quantity of an item that will be required to support the weapon system during its activation period.




```
1025A WID2.K=(IFOB.K+SMDR.K-WISSL.K)(NOISE2.K)
1050NOTE      WID2     -WORLDWIDE ISSL DISCREPANCY 2
1075NOTE      IFOB     -INPUT FROM OTHER BASES
1100NOTE      SMDR     -SMOOTHED MONTHLY DEMAND RATE
1125NOTE      WISSL    -WORLDWIDE ISSL
1150NOTE      NOISE2   -NOISE 2
1175A SMDR.K=(30)(SMOOTH(NEWDDR.K,SP))
1200NOTE      SMDR     -SMOOTHED MONTHLY DEMAND RATE
1225NOTE      NEWDDR   -NEW DAILY DEMAND RATE
1250NOTE      SP       -SMOOTHING PERIOD
1275A IFOB.K=(SMDR.K/FEIB.K)-SMDR.K
1300NOTE      IFOB     -INPUT FROM OTHER BASES
1325NOTE      SMDR     -SMOOTHED MONTHLY DEMAND RATE
1350NOTE      FEIB     -FRACTION OF END ITEMS ON BASE
1375A FEIB.K=NEIB/TNEI
1400NOTE      FEIB     -FRACTION OF END ITEMS ON BASE
1425NOTE      NEIB     -NUMBER OF END ITEMS ON BASE
1450NOTE      TNEI     -TOTAL NUMBER OF END ITEMS
1475A NOISE2.K=NORMRN(1.0,0.2)
1500NOTE      NOISE2   -NOISE 2
```

Figure 4-4. ISSL Development Sector Diagram 4

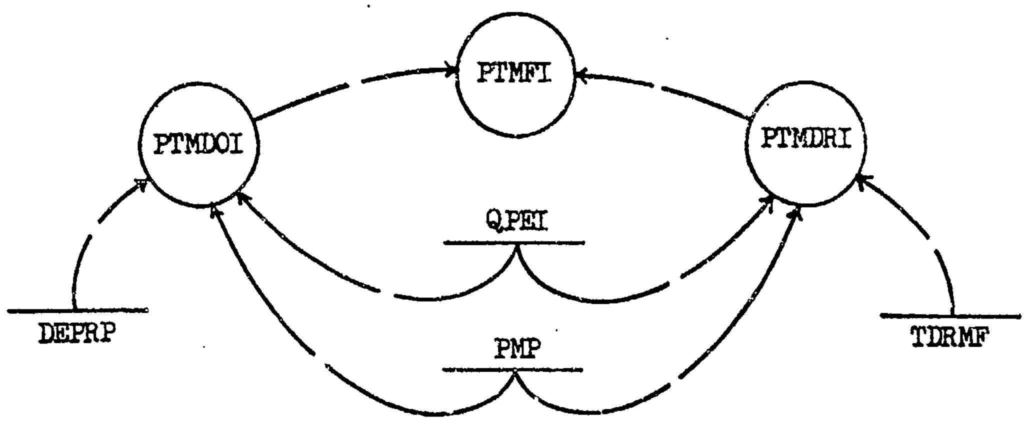
It is calculated on the AFLC Form 997, EOQ Initial Provisioning Worksheet, using the equations in Chapter 2 of AFLCR 57-27, Initial Requirements Determination. The data used in the calculations are obtained from the provisioning documents and was discussed in Chapter III. Figure 4-5 illustrates that the Initial Worldwide ISSL is the sum of the Order and Ship Time Requirement and the Repair Cycle




```
1525A IWISSL.K=OSTR.K+RCR.K
155ØNOTE      IWISSL  -INITIAL WORLDWIDE ISSL
1575NOTE      OSTR    -ORDER AND SHIP TIME REQUIREMENT
16ØØNOTE      RCR     -REPAIR CYCLE REQUIREMENT
1625A OSTR.K=(BOST.K)(PTMFI.K)(CP.K)
165ØNOTE      OSTR    -ORDER AND SHIP TIME REQUIREMENT
1675NOTE      BOST    -BASE ORDER AND SHIP TIME
17ØØNOTE      PTMFI   -PEAK TOTAL MONTH FIELD ISSUES
1725NOTE      CP      -CONDEMNATION PERCENT
175ØA BOST.K=OST/3Ø   MONTHS
1775NOTE      BOST    -BASE ORDER AND SHIP TIME
18ØØNOTE      OST     -ORDER AND SHIP TIME
1825A RCR.K=(BRC.K)(PTMFI.K)(1.ØØ-CP.K)
185ØNOTE      RCR     -REPAIR CYCLE REQUIREMENT
1875NOTE      BRC     -BASE REPAIR CYCLE
19ØØNOTE      PTMFI   -PEAK TOTAL MONTH FIELD ISSUES
1925NOTE      CP      -CONDEMNATION PERCENT
```

Figure 4-5. ISSL Development Sector Diagram 5

Requirement. The Order and Ship Time Requirement is the product of three factors: the Base Order and Ship Time, the Peak Total Month Field Issues, and the Condemnation Percent. The Base Order and Ship Time equals the Order and Ship Time divided by thirty.




```
1950A PTMFI.K=PTMDRI.K-PTMDOI.K
1975NOTE      PTMFI   -PEAK TOTAL MONTH FIELD ISSUES
2000NOTE      PTMDRI  -PEAK TOTAL MONTH DEMAND RATE ISSUES
2025NOTE      PTMDOI  -PEAK TOTAL MONTH DEPOT OVERHAUL ISSUES
2050A PTMDOI.K=(DEPRP.K)(QPEI)(PMP.K)
2075NOTE      PTMDOI  -PEAK TOTAL MONTH DEPOT OVERHAUL ISSUES
2100NOTE      DEPRP   -DEPOT REPLACEMENT PERCENT
2125NOTE      QPEI    -QUANTITY OF PARTS PER END ITEM
2150NOTE      PMP     -PEAK MONTH PROGRAM
2175A PTMDRI.K=(TDRMF.K)(QPEI)(PMP.K)
2200NOTE      PTMDRI  -PEAK TOTAL MONTH DEMAND RATE ISSUES
2225NOTE      TDRMF   -TOTAL DEMAND RATE MAINTENANCE FACTOR
2250NOTE      QPEI    -QUANTITY OF PARTS PER END ITEM
2275NOTE      PMP     -PEAK MONTH PROGRAM
```

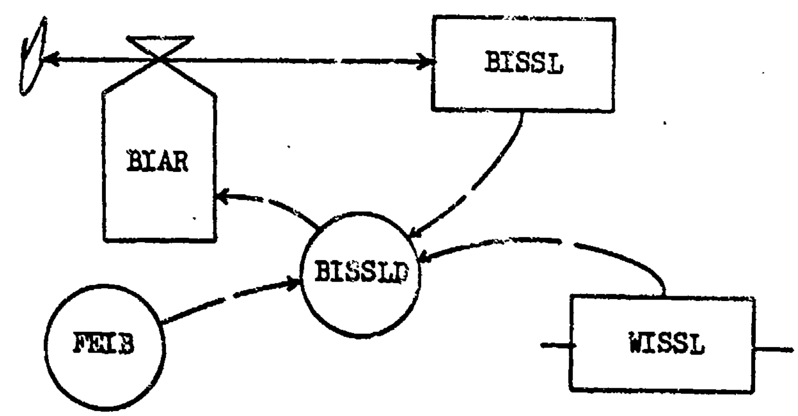
Figure 4-6. ISSL Development Sector Diagram 6

The Repair Cycle Requirement is also the product of three factors; the Base Repair Cycle, the Peak Total Month Field Issues, and one minus the Condemnation Percent.

Figure 4-6 shows that the Peak Total Month Field Issues is a function of two factors: the Peak Total Month Depot Overhaul

Issues and the Peak Total Month Demand Rate Issues. The Peak Total Month Depot Overhaul Issues is the product of the Depot Replacement Percent, the Total Quantity Installed per End Item, and the Peak Month Program. The Peak Month Demand Rate Issues is the product of the Total Demand Rate Maintenance Factor, the Total Quantity Installed per End Item, and the Peak Month Program.

The Base level ISSL is the second part of the ISSL development sector. It is the quantity of an item that is required at base level to support a weapon system until normal demand rates are established.




```
2300L BISSL.K=BISSL.J+(DT)(BIAR.JK)
2325NOTE      BISSL   -BASE ISSL
2350NOTE      DT      -DELTA TIME
2375NOTE      BIAR    -BASE ISSL ADJUSTMENT RATE
2400R BIAR.KL=BISSLD.K
2425NOTE      BIAR    -BASE ISSL ADJUSTMENT RATE
2450NOTE      BISSLD  -BASE ISSL DISCREPANCY
2475A BISSLD.K=(WISSL.K)(FEIB.K)-BISSL.K
2500NOTE      BISSLD  -BASE ISSL DISCREPANCY
2525NOTE      WISSL   -WORLDWIDE ISSL
2550NOTE      FEIB    -FRACTION OF END ITEMS ON BASE
2575NOTE      BISSL   -BASE ISSL
```

Figure 4-7. ISSL Development Sector Diagram 7

It is a function of the Base ISSL Adjustment Rate as shown in Figure 4-7.

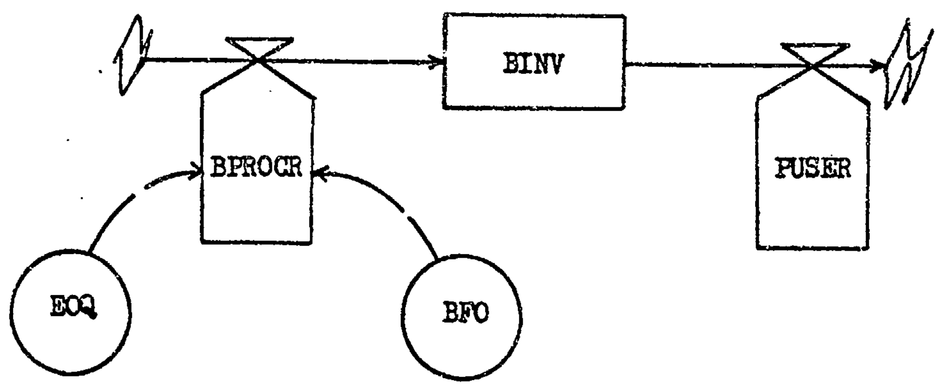
The Base ISSL Adjustment Rate is a function of the Base ISSL Discrepancy; i.e., the difference between the current Base ISSL level and the updated Base ISSL. The three factors that determine the value of the Base ISSL Discrepancy (the Worldwide ISSL level, the Base ISSL level, and the Fraction of End Items on Base) have all previously been discussed in this section.

This concludes the discussion of the ISSL development sector. The Base Inventory sector is discussed next.

Base Inventory Sector

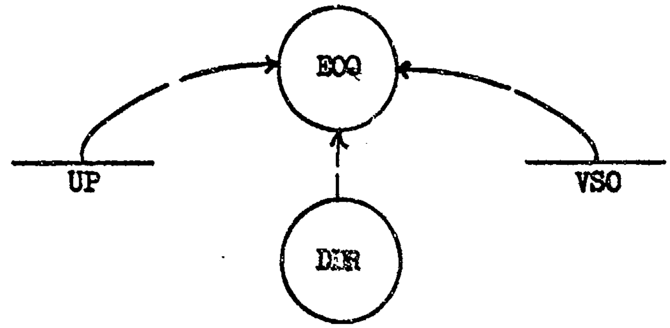
For purposes of discussion, the Base Inventory Sector has been divided into two subsectors: the Inventory Subsector which describes the actual movement of items through the base, and the Daily Demand Rate Adjustment Subsector which is concerned with the flow of information about the movement of those items and how that information is used. The Inventory Subsector will be discussed first.

Inventory Subsector. The central variable in this sector is the level of the Base Inventory. This level is the quantity of the item under study that is actually in stock in base supply. Figure 4-8 illustrates that this level is determined by the Parts Use Rate and the Base Procurement Rate. Parts Use Rate is a part of the Consumption Sector and will be discussed later in this chapter. The Base Procurement Rate is a function of the Base Economic Order Quantity and the Base Fraction Ordered.




```
3925L BINV.K=BINV.J+(DT)(BPROCR.JK-PUSER.JK)
3950NOTE      BINV    -BASE INVENTORY
3975NOTE      BPROCR  -BASE PROCUREMENT RATE
4000NOTE      PUSER   -PARTS USE RATE
4025R BPROCR.KL=(EOQ.K)(BFO.K)
4050NOTE      BPROCR  -BASE PROCUREMENT RATE
4075NOTE      EOQ     -BASE ECONOMIC ORDER QUANTITY
4100NOTE      BFO     -BASE FRACTION ORDERED
```

Figure 4-8. Base Inventory Sector Diagram 1



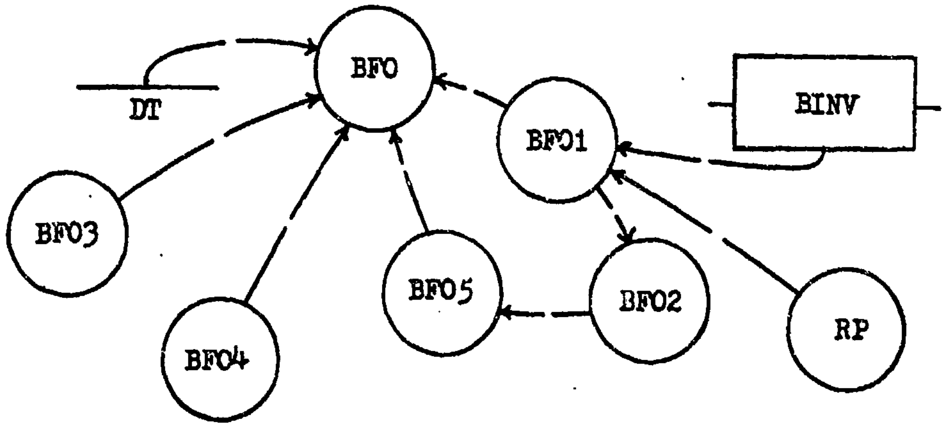

```
4125A EOQ.K=((4.4)(SQRT((DDR.K)(VSO)(UP))))/(UP)
4150NOTE      EOQ     -BASE ECONOMIC ORDER QUANTITY
4175NOTE      DDR     -DAILY DEMAND RATE
4200NOTE      VSO     -VARIABLE STOCKAGE OBJECTIVE
4225NOTE      UP      -UNIT PRICE
```

Figure 4-9. Base Inventory Sector Diagram 2

As illustrated in Figure 4-9, the Base Economic Order Quantity is a function of three factors; the Unit Price of the item being procured, the Variable Stockage Objective, and the Daily Demand Rate. These three factors are combined in the following manner to yeild the Economic Order Quantity: $EOQ = \frac{4.4\sqrt{(DDR)(VSO)(UP)}}{UP}$.

Both the Variable Stockage Objective and the Unit Price are constants that are peculiar to the particular item under study. The Daily Demand Rate will be discussed later.

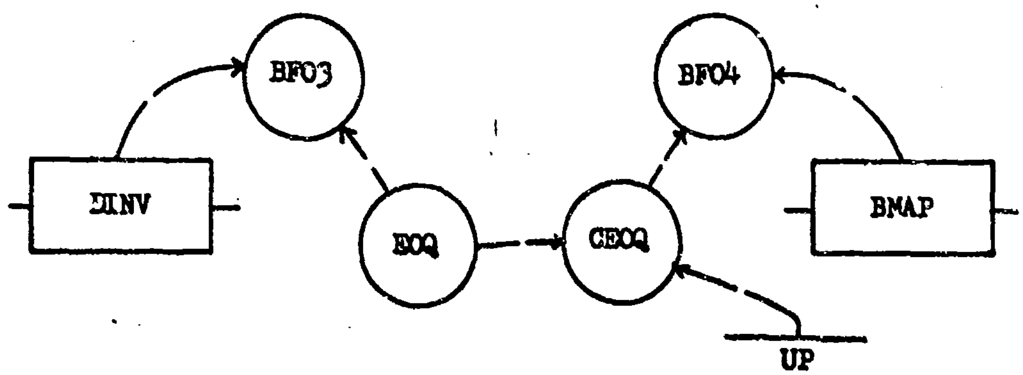
The Base Fraction Ordered is a combination of five factors: Delta Time and the Base Fraction Ordered factors 1,3,4, and 5. This is illustrated in Figure 4-10. Base Fraction Ordered factors 1 and 5 are timing factors that "order" parts from the Depot whenever the Base Inventory is depleted to the extent that it reaches the Base Reorder Point.




```
4250A BFO.K=(BFO1.K)(BFO5.K)(MIN(BFO3.K,BFO4.K))(1/DT)
4275NOTE      BFO     -BASE FRACTION ORDERED
4300NOTE      BFO1    -BASE FRACTION ORDERED 1
4325NOTE      BFO5    -BASE FRACTION ORDERED 5
4350NOTE      BFO3    -BASE FRACTION ORDERED 3
4375NOTE      BFO4    -BASE FRACTION ORDERED 4
4400NOTE      DT      -DELTA TIME
4425A BFO1.K=CLIP(0,1,BINV.K,RP.K)
4450NOTE      BFO1    -BASE FRACTION ORDERED 1
4475NOTE      BINV    -BASE INVENTORY
4500NOTE      RP      -BASE REORDER POINT
4525L BFO2.K=CLIP(0,1,BFO1.J,0.5)
4550NOTE      BFO2    -BASE FRACTION ORDERED 2
4575NOTE      BFO1    -BASE FRACTION ORDERED 1
```

Figure 4-10. Base Inventory Sector Diagram 3

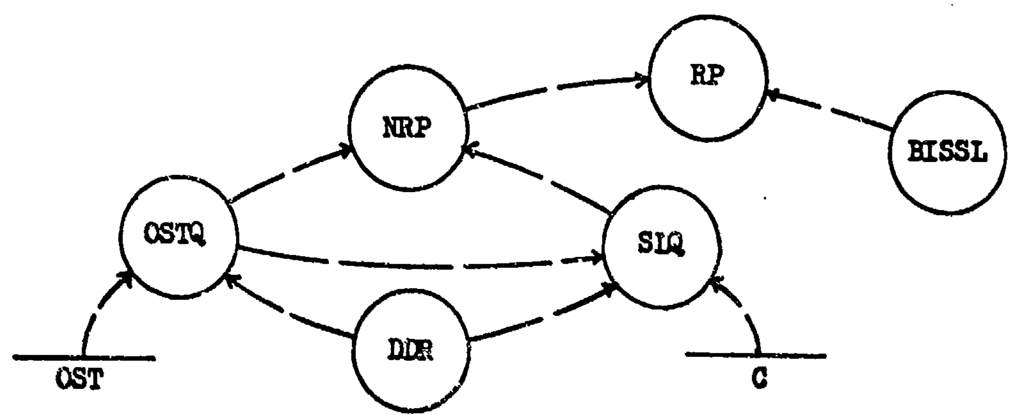
Figure 4-11 illustrates that factor 3 limits the quantity of parts that are "shipped" to the base to the number of parts that are available from the Depot. This factor prevents the Depot Inventory from going negative if a situation should develop in which an order from the Base exceeds the current Depot Inventory. Factor 4 is a function of the Cost of the Economic Order Quantity and the amount of money that the base has available for the procurement of parts. This factor prevents the base from ordering more parts than it can pay for. The Cost of the Base Economic Order Quantity is equal to the Base Economic Order Quantity times the Unit Price of the item being procured.




```
4675A BF03.K=CLIP(1,(DINV.K/EOQ.K),(DINV.K-EOQ.K),0)
4700NOTE     BF03    -BASE FRACTION ORDERED 3
4725NOTE     DINV    -DEPOT INVENTORY
4750NOTE     EOQ     -BASE ECONOMIC ORDER QUANTITY
4775A BF04.K=CLIP(1,(BMAP.K/CEOQ.K),(BMAP.K-CEOQ.K),0)
4800NOTE     BF04    -BASE FRACTION ORDERED 4
4825NOTE     BMAP    -BASE MONEY AVAILABLE FOR PROCUREMENT
4850NOTE     CEOQ    -COST OF BASE ECONOMIC ORDER QUANTITY
4875A CEOQ.K=(EOQ.K)(UP)
4900NOTE     CEOQ    -COST OF BASE ECONOMIC ORDER QUANTITY
4925NOTE     EOQ     -BASE ECONOMIC ORDER QUANTITY
4950NOTE     UP      -UNIT PRICE
```

Figure 4-11. Base Inventory Sector Diagram 4

Figure 4-12 illustrates that the Base Reorder Point is equal to either the Base ISSL divided by three or the Normal Reorder Point, whichever is greater (see Chapter III). The Base ISSL was discussed in the ISSL Development Sector. The Normal Reorder Point is the sum of the Order and Ship Time Quantity and the Safety Level Quantity.

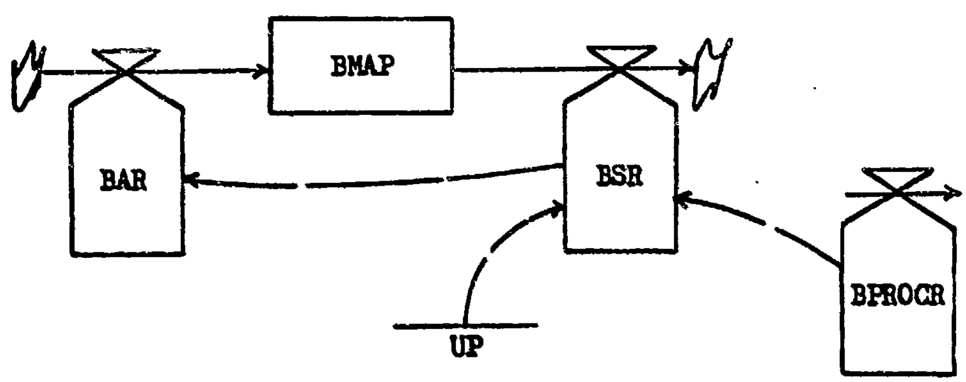



```
4975A RP.K=MAX((BISSL.K/3),NRP.K)
5000NOTE     RP      -BASE REORDER POINT
5025NOTE     BISSL   -BASE INITIAL SPARES SUPPORT LIST
5050NOTE     NRP     -NORMAL REORDER POINT
5075A NRP.K=OSTQ.K+SLQ.K
5100NOTE     NRP     -NORMAL REORDER POINT
5125NOTE     OSTQ    -ORDER AND SHIP TIME QUANTITY
5150NOTE     SLQ     -SAFETY LEVEL QUANTITY
5175A OSTQ.K=(DDR.K)(OST)
5200NOTE     OSTQ    -ORDER AND SHIP TIME QUANTITY
5225NOTE     DDR     -DAILY DEMAND RATE
5250NOTE     OST     -ORDER AND SHIP TIME
5275A SLQ.K=MAX((C)(SQRT((3)(OSTQ.K))),(DDR.K)(15))
5300NOTE     SLQ     -SAFETY LEVEL QUANTITY
5325NOTE     C       -CONSTANT
5350NOTE     OSTQ    -ORDER AND SHIP TIME QUANTITY
5375NOTE     DDR     -DAILY DEMAND RATE
```

Figure 4-12. Base Inventory Sector Diagram 5

The Order and Ship Time Quantity equals the Order and Ship Time multiplied by the Daily Demand Rate. The Safety Level Quantity is equal to either C times the square root of three times the Order and Ship Time Quantity ($C\sqrt{(3)(OSTQ)}$), or fifteen times the Daily Demand Rate, whichever is greater. C is a constant determined by Headquarters United States Air Force that is normally equal to 1. The Daily Demand Rate is discussed in the Daily Demand Rate Adjustment Subsector.

Figure 4-13 illustrates how the money that is available for the procurement of ISSL items flows through the base. As was



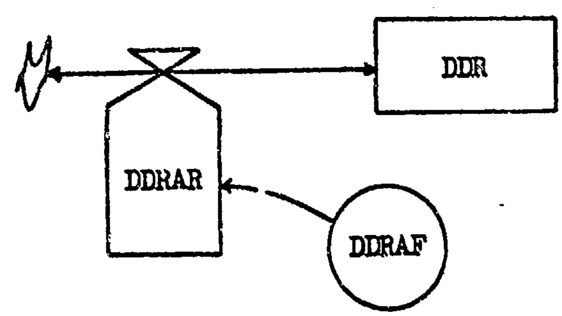

```
5400L BMAP.K=BMAP.J+(DT)(BAR.JK-BSR.JK)
5425NOTE      BMAP    -BASE MONEY AVAILABLE FOR PROCUREMENT
5450NOTE      DT      -DELTA TIME
5475NOTE      BAR     -BASE APPROPRIATION RATE
5500NOTE      BSR     -BASE SPENDING RATE
5525R BAR.KL=BSR.JK
5550NOTE      BAR     -BASE APPROPRIATION RATE
5575NOTE      BSR     -BASE SPENDING RATE
5600R BSR.KL=(BPROCR.JK)(UP)
5625NOTE      BSR     -BASE SPENDING RATE
5650NOTE      BPROCR  -BASE PROCUREMENT RATE
5675NOTE      UP      -UNIT PRICE
```

Figure 4-13. Base Inventory Sector Diagram 6

discussed in Chapter III, this money is generally made available to the base supply system and seldom presents anything more than a temporary problem. For this reason, the model was constructed to ensure that the base always has adequate funds to purchase ISSL items. The amount of Money Available for Procurement is a function of the Base Appropriation Rate and the Base Spending Rate. The Base Appropriation Rate was made equal to the Base Spending Rate. The Base Spending Rate equals the Base Procurement Rate times the Unit Price of the item being procured. The Base Procurement Rate was discussed earlier in this section and the Unit Price is a constant that is peculiar to the item being procured.

This concludes the discussion of the Base Inventory Subsector. The Daily Demand Rate Adjustment Subsector will be discussed next.

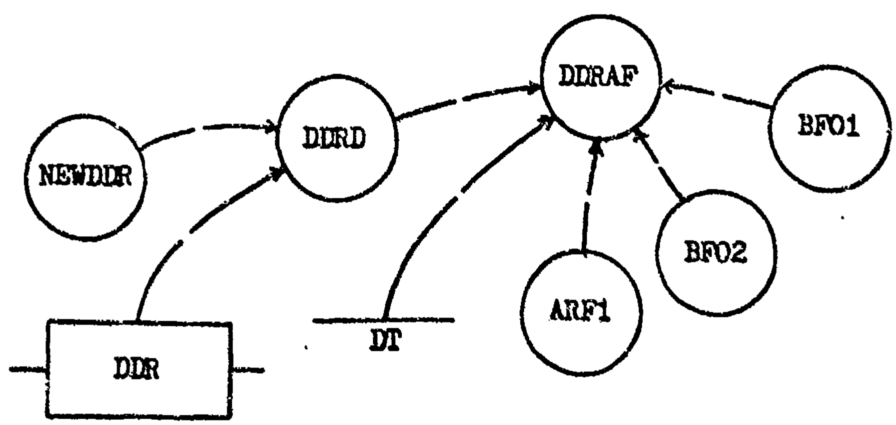
Daily Demand Rate Adjustment Subsector. The variable "Daily Demand Rate" is the periodically updated average daily demand for the item under study. It is the central variable of this subsector. Figure 4-14 illustrates that it is controlled by the Daily Demand Rate Adjustment Rate. The Daily Demand Rate Adjustment Rate is, in turn, controlled by the Daily Demand Rate Adjustment Factor.




```
635ØL DDR.K=DDR.J+(DT)(DDRAR.JK)
6375NOTE      DDR    -DAILY DEMAND RATE
6376NOTE      DT     -DELTA TIME
6377NOTE      DDRAR  -DAILY DEMAND RATE ADJUSTMENT RATE
64ØØR DDRAR.KL=DDRAF.K
6425NOTE      DDRAR  -DAILY DEMAND RATE ADJUSTMENT RATE
645ØNOTE      DDRAF  -DAILY DEMAND RATE ADJUSTMENT FACTOR
```

Figure 4-14. Base Inventory Sector Diagram 7

Figure 4-15 identifies the five factors that determine the value of the Daily Demand Rate Adjustment Factor. They are: the Daily Demand Rate Discrepancy, Base Fraction Ordered factors 1 and 2, Adjustment Rate Factor 1, and Delta Time. The Daily Demand Rate Discrepancy is the difference between the Daily Demand Rate, which is an information level that is updated periodically, and the New Daily Demand Rate which is an auxiliary variable that is updated continually and will be explained later.




```
6475A DDRAF.K=(DDRD.K)(BFO1.K)(BFO2.K)(ARF1.K)(1/DT)
65ØØNOTE     DDRAF   -DAILY DEMAND RATE ADJUSTMENT FACTOR
6525NOTE     DDRD    -DAILY DEMAND RATE DISCREPANCY
655ØNOTE     BFO1    -BASE FRACTION ORDERED 1
6575NOTE     BFO2    -BASE FRACTION ORDERED 2
66ØØNOTE     ARF1    -ADJUSTMENT RATE FACTOR 1
6625NOTE     DT      -DELTA TIME
665ØA DDRD.K=NEWDDR.K-DDR.K
6675NOTE     DDRD    -DAILY DEMAND RATE DISCREPANCY
67ØØNOTE     NEWDDR  -NEW DAILY DEMAND RATE
6725NOTE     DDR     -DAILY DEMAND RATE
```

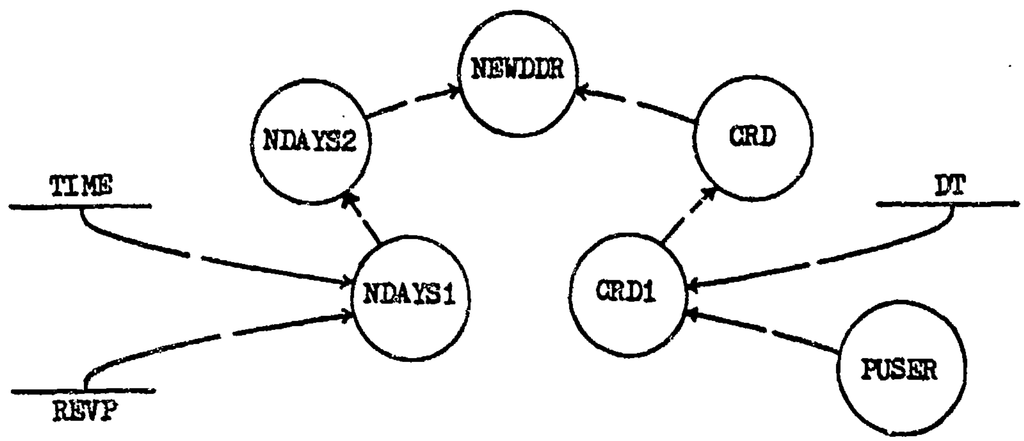
Figure 4-15. Base Inventory Sector Diagram 8

Base Fraction Ordered factors 1 and 2 and the Adjustment Rate Factor 1 are timing factors that permit the adjustment of the Daily Demand Rate only at specific times and only if certain conditions are satisfied. Base Fraction Ordered factors 1 and 2 were discussed in the Base Inventory Subsector. They are used here to limit the adjustment of the Daily Demand Rate to the points in time immediately prior to the depot filling orders for parts from the base.

Adjustment Rate Factor 1 allows adjustment of the Daily Demand Rate only if the magnitude of the adjustment meets certain criteria that are discussed later in this section. Both the timing conditions imposed by the Base Fraction Ordered factors and the magnitude of change conditions imposed by the Adjustment Rate Factor must be satisfied before the Daily Demand Rate can be adjusted.

If the base places an order for parts and the Daily Demand Rate is adjusted, the Base Economic Order Quantity and Reorder Point are immediately revised and the order is filled based on the revised Economic Order Quantity. Subsequent orders are filled based on the revised Reorder Point and Economic Order Quantity.

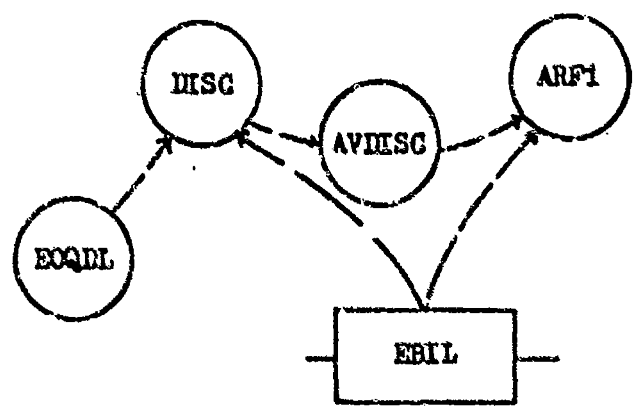
The New Daily Demand Rate in Figure 4-15 is an average Daily Demand Rate that is updated daily. It is equal to the Cumulative Recurring Demand over a given review period divided by the length of the review period (REVP). Figure 4-16 illustrates the variables that are required to make the program properly comute and update the New Daily Demand Rate.




```
6750A NEWDDR.K=CRD.K/NDAYS2.K
6775NOTE      NEWDDR  -NEW DAILY DEMAND RATE
6800NOTE      CRD     -CUMULATIVE RECURRING DEMAND
6825NOTE      NDAYS2  -NUMBER OF DAYS 2
6850C REVPI=45    DAYS
6875NOTE      REVPI   -REVIEW PERIOD (INITIAL)
6900FOR I=1,REVPI
6925NOTE      I       -REVIEW PERIOD COUNTER
6950NOTE      REVPI   -REVEIW PERIOD (INITIAL)
6975A CRD.K=SUM(CRD1.K)
6976NOTE      CRD     -CUMULATIVE RECURRING DEMAND
7000NOTE      CRD1    -CUMULATIVE RECURRING DEMAND 1
7025L CRD1.K(I)=(PUSER.JK)(DT)+CRD1.J(I)
7050NOTE      CRD1    -CUMULATIVE RECURRING DEMAND 1
7075NOTE      PUSER   -PARTS USE RATE
7100NOTE      DT      -DELTA TIME
7125A NDAYS2.K=CLIP(NDAYS1.K,1,NDAYS1.K,1)
7150NOTE      NDAYS2  -NUMBER OF DAYS 2
7175NOTE      NDAYS1  -NUMBER OF DAYS 1
7200A NDAYS1.K=CLIP(REVP.K,TIME.K,TIME.K,REVP.K)
7225NOTE      NDAYS1  -NUMBER OF DAYS 1
7250NOTE      REVP    -REVIEW PERIOD
7275NOTE      TIME    -TIME
```

Figure 4-16. Base Inventory Sector Diagram 9

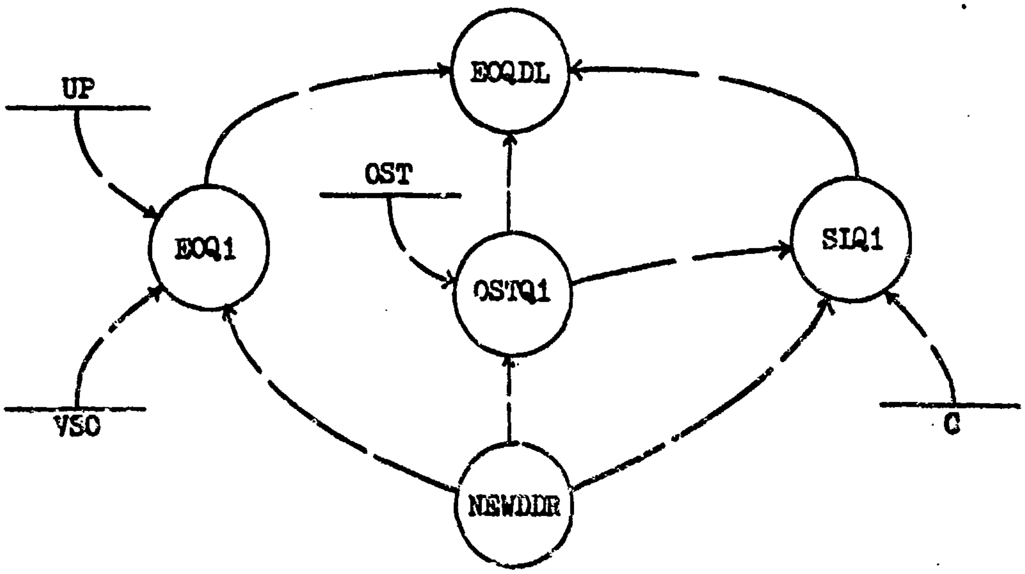
The Adjustment Rate Factor 1 is the final variable that influences the Daily Demand Rate Adjustment Factor. It is the timing factor that determines whether or not the Daily Demand Rate (and thus the Base Economic Order Quantity and Base Reorder Point) is updated when the base places an order for parts. Figure 4-17 shows that two variables act to determine the value of the Adjustment Rate Factor 1: the Established Base Inventory Level and the absolute value of the difference between the Economic Order Quantity Demand Level and the Established Base Inventory Level. If the difference is greater than the square root of the Established Base Inventory Level, both the Daily Demand Rate and the Established Base Inventory Level are updated; if not, no change is permitted (see Chapter III).




```
7300A ARF1.K=CLIP(1,0,(AVDISC.K-SQRT(EBIL.K)),0)
7325NOTE      ARF1    -ADJUSTMENT RATE FACTOR 1
7350NOTE      AVDISC  -ABSOLUTE VALUE OF DISC
7375NOTE      EBIL    -ESTABLISHED BASE INVENTORT LEVEL
7400A DISC.K=EOQDL.K-EBIL.K
7425NOTE      DISC    -DISCREPANCT
7450NOTE      EOQDL   -BASE EOQ DEMAND LEVEL
7475NOTE      EBIL    -ESTABLISHED BASE INVENTORY LEVEL
7500A AVDISC.K=MAX(DISC.K,-DISC.K)
7525NOTE      AVDISC  -ARSOLUTE VALUE OF DISC
7550NOTE      DISC    -DISCREPANCT
```

Figure 4-17. Base Inventory Sector Diagram 10

Figure 4-18 illustrates that the Economic Order Quantity Demand Level is equal to the sum of the Economic Order Quantity 1, the Order and Ship Time Quantity 1, and the Safety Level Quantity 1.

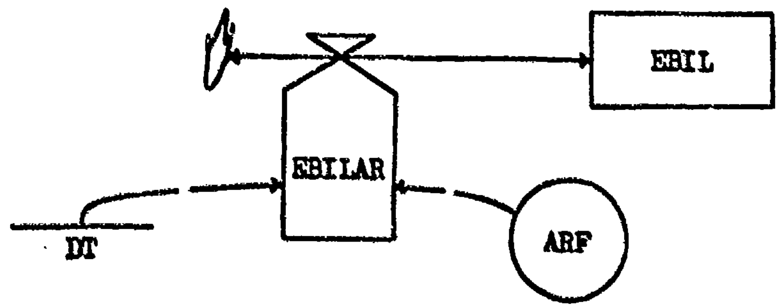



```
7575A EOQDL.K=EOQ1.K+OSTQ1.K+SLQ1.K
7600NOTE       EOQDL   -BASS EOQ DEMAND LEVEL
7625NOTE       EOQ1    -BASE ECONOMIC ORDER QUANTITY 1
7650NOTE       OSTQ1   -ORDER AND SHIP TIME QUANTITY 1
7675NOTE       SLQ1    -SAFETY LEVEL QUANTITY 1
7700A EOQ1.K=((4.4)(SQRT((NEWDDR.K)(VSO)(UP))))/(UP)
7725NOTE       EOQ1    -BASE ECONOMIC ORDER QUANTITY 1
7750NOTE       NEWDDR  -NEW DAILY DEMAND RATE
7775NOTE       VSO     -VARIABLE STOCKAGE OBJECTIVE
7800NOTE       UP      -UNIT PRICE
7825A OSTQ1.K=(NEWDDR.K)(OST)
7850NOTE       OSTQ1   -ORDER AND SHIP TIME QUANTITY 1
7875NOTE       NEWDDR  -NEW DAILY DEMAND RATE
7900NOTE       OST     -ORDER AND SHIP TIME
7925A SLQ1.K=MAX((C)(SQRT((3)(OSTQ1.K))),(NEWDDR.K)(15))
7950NOTE       SLQ1    -SAFETY LEVEL QUANTITY 1
7975NOTE       C       -CONSTANT
8000NOTE       OSTQ1   -ORDER AND SHIP TIME QUANTITY 1
8025NOTE       NEWDDR  -NEW DAILY DEMAND RATE
```

Figure 4-18. Base Inventory Sector Diagram 11

These three factors are determined in the same manner as the Economic Order Quantity, the Order and Ship Time Quantity, and the Safety Level Quantity that were previously discussed in the Inventory Subsector, except that the New Daily Demand Rate, not the Daily Demand Rate, is used in the calculation.

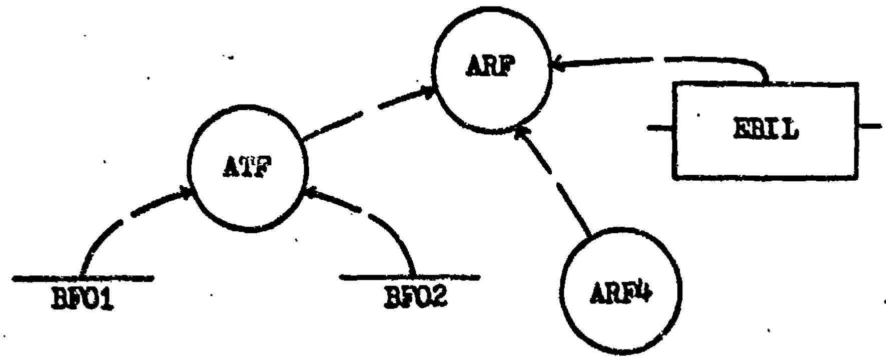
The Established Base Inventory Level is the second factor that is used to calculate the discrepancy in Figure 4-17. It serves as a point of reference for determining when to revise the Daily Demand Rate. Figure 4-19 illustrates that it is a function of the Established Base Inventory Level Adjustment Rate. The adjustment rate is, in turn, a function of the Adjustment Rate Factor and Delta Time.




```
8050L EBIL.K=EBIL.J+(DT)(EBILAR.JK)
8075NOTE     EBIL     -ESTABLISHED BASE INVENTORY LEVEL
8100NOTE     DT       -DELTA TIME
8125NOTE     EBILAR   -EBIL ADJUSTMENT RATE
8150R EBILAR.KL=(1/DT)(ARF.K)
8175NOTE     EBILAR   -EBIL ADJUSTMENT RATE
8200NOTE     DT       -DELTA TIME
8225NOTE     ARF      -ADJUSTMENT RATE FACTOR
```

Figure 4-19. Base Inventory Sector Diagram 12

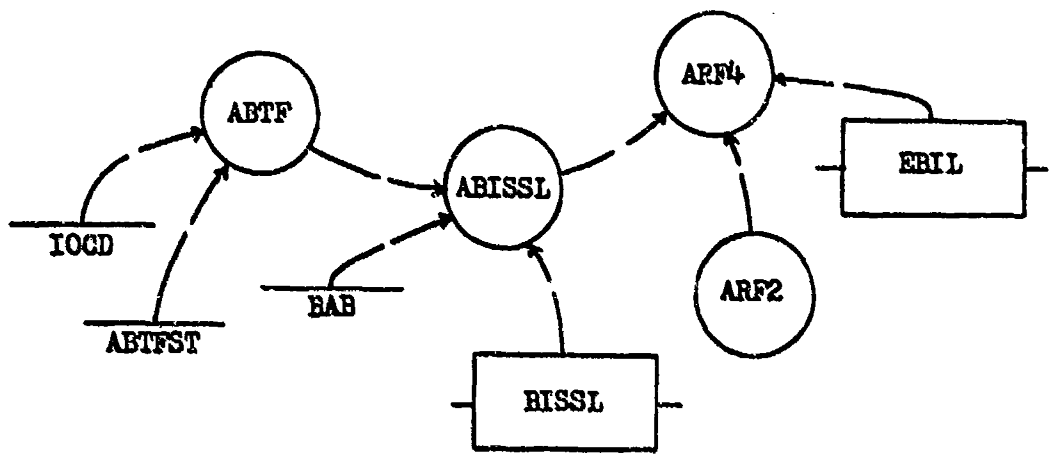
The Adjustment Rate Factor is the amount of the change to be made in the Established Base Inventory Level at any given point in time. It is composed of the three elements that are illustrated in Figure 4-20. The Adjustment Timing Factor is the product of Base Fraction Ordered factors 1 and 2 and permits the Established Base Inventory Level to be adjusted only when the base submits an order for parts from the depot. Adjustment Rate Factor 4 is the value that the Established Base Inventory Level "should be" at a given point in time.




```
8250A ARF.K=(ARF4.K-EBIL.K)(ATF.K)
8275NOTE      ARF     -ADJUSTMENT RATE FACTOR
8300NOTE      ARF4    -ADJUSTMENT RATE FACTOR 4
8325NOTE      EBIL    -ESTABLISHED BASE INVENTORY LEVEL
8350NOTE      ATF     -ADJUSTMENT TIMING FACTOR
8375A ATF.K=(BFO1.K)(BFO2.K)
8400NOTE      ATF     -ADJUSTMENT TIMING FACTOR
8425NOTE      BFO1    -BASE FRACTION ORDERED 1
8450NOTE      BFO2    -BASE FRACTION ORDERED 2
```

Figure 4-20. Base Inventory Sector Diagram 13

Figure 4-21 illustrates that the Adjustment Rate Factor 4 is a function of three elements: the Established Base Inventory Level, the Adjusted Base ISSL, and the Adjustment Rate Factor 2. The equation selects the maximum of the adjusted currently Established Base Inventory Level or the Adjusted Base ISSL as the desired future Established Base Inventory Level.



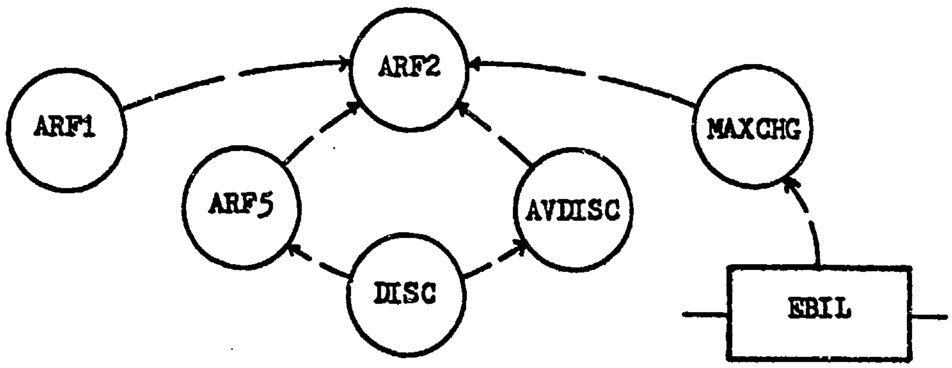

```
8475A ARF4.K=SWITCH((ARF2.K+EBIL.K),
85ØØX (MAX(ARF2.K+EBIL.K,ABISSL.K)),ABISSL.K)
8525NOTE      ARF4    -ADJUSTMENT RATE FACTOR 4
855ØNOTE      ARF2    -ADJUSTMENT RATE FACTOR 2
8575NOTE      EBIL    -ESTABLISHED BASE INVENTORY LEVEL
86ØØNOTE      ABISSL  -ADJUSTED BASE ISSL
8625A ABISSL.K=(BAB)(BISSL.K)(ABTF.K)
865ØNOTE      ABISSL  -ADJUSTED BASE ISSL
8675NOTE      BAB     -BASE ADJUSTMENT TO THE BASE ISSL
8676NOTE      BISSL   -BASE ISSL
87ØØNOTE      ABTF    -ADJUSTED BASE ISSL TIMING FACTOR
8725A ABTF.K=STEP(1,ABTFST)+STEP(-1,IOCD+73Ø)
875ØNOTE      ABTF    -ADJUSTED BASE ISSL TIMING FACTOR
8775NOTE      ABTFST  -ABTF STEP TIME
88ØØNOTE      IOCD    -INITIAL OPERATION CAPABLE DATE
```

Figure 4-21. Base Inventory Sector Diagram 14

The Adjusted Base ISSL equals the Base ISSL (as discussed in the ISSL Development Sector) multiplied by the Base Adjustment to the Base ISSL and the Adjusted Base ISSL Timing Factor. The Base Adjustment to the Base ISSL is a modification to the Base ISSL level that is jointly determined by the using organization and its parent major command. The Adjusted Base ISSL Timing Factor determines the point in time at which the ISSL requirement is levied on the base. It also removes the ISSL requirement from the base 730 days after the Initial Operation Capable Date of the weapon system at that base.

The Adjustment Rate Factor 2 in Figure 4-21 is the numerical value of the desired change in the Established Base Inventory Level. Figure 4-22 illustrates that it is composed of four factors: Adjustment Rate Factors 1 and 5, the absolute value of the difference between the Established Base Inventory Level and the Economic Order Quantity Demand Level, and the maximum permitted change. The equation compares the absolute value of the difference between the Established Base Inventory Level and the Economic Order Quantity Demand Level with the maximum allowable change in the Established Base Inventory Level, multiplies this by the Adjustment Rate Factor 5 to obtain the proper algebraic sign, and finally multiplies the change by the Adjustment Rate Factor 1 to obtain the proper timing.

The Adjustment Rate Factor 5 establishes the proper sign of the Adjustment Rate Factor 2. It is a function of the difference between the Economic Order Quantity Demand Level and the Established




```
8825A ARF2.K=(MIN(AVDISC.K,MAXCHG.K))(ARF1.K)(ARF5.K)
8850NOTE      ARF2    -ADJUSTMENT RATE FACTOR 2
8875NOTE      AVDISC  -ABSOLUTE VALUE OF DISC
8900NOTE      MAXCHG  -MAXIMUM CHANGE
8925NOTE      ARF1    -ADJUSTMENT RATE FACTOR 1
8950NOTE      ARF5    -ADJUSTMENT RATE FACTOR 5
8975A ARF5.K=CLIP(1,-1,DISC.K,0)
9000NOTE      ARF5    -ADJUSTMENT RATE FACTOR 5
9025NOTE      DISC    -DISCREPANCY
9050A MAXCHG.K=SQRT(EBIL.K)
9075NOTE      MAXCHG  -MAXIMUM CHANGE
9100NOTE      EBIL    -ESTABLISHED BASE INVENTORY LEVEL
```

Figure 4-22. Base Inventory Sector Diagram 15

Base Inventory Level. If the demand level is greater than the established inventory, Adjustment Rate Factor 5 is positive; if the demand level is less than the established inventory, Adjustment Rate Factor 5 is negative. The absolute value of the difference between the Economic Order Quantity demand level and the established base level is the mathematical absolute value of the difference. The maximum allowable change for the Established Base Inventory Level is equal to the square root of the level at that point in time (see Chapter III).

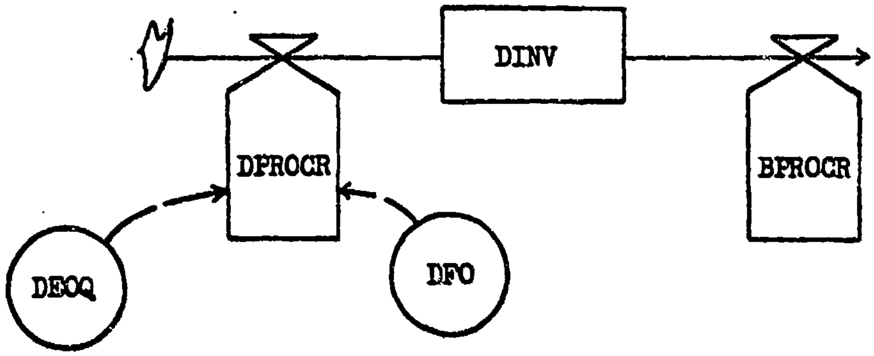
This concludes the discussion of the Base Inventory Sector. The Depot Inventory Sector is described next.

## Depot Inventory Sector

The function of this sector is to briefly describe the process of acquiring parts and providing them to the Base Inventory Sector. The sector did not have to be thoroughly developed in order to accomplish this function and it was designed to satisfy all demands from the base.

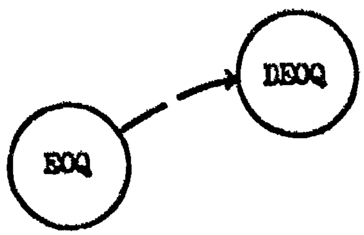
The central variable in the sector is the level of Depot Inventory. Figure 4-23 illustrates that it is determined entirely by the Base Procurement Rate (which was described in the Base Inventory Sector) and the Depot Procurement Rate. The Depot Procurement Rate is a function of the Depot Economic Order Quantity and the Depot Fraction Ordered.

Figure 4-24 illustrates that the Depot Economic Order Quantity is a function of the Base Economic Order Quantity. It is the number of items that the depot orders each time it places an order for the items under study. It was set to equal five times the Base Economic Order Quantity in order to ensure that the Depot Inventory Sector would always be able to satisfy requirements imposed by the base.




```
9875L DINV.K=DINV.J+(DT)(DPROCR.JK-BPROCR.JK)
9900NOTE     DINV    -DEPOT INVENTORY
9925NOTE     DPROCR  -DEPOT PROCUREMENT RATE
9950NOTE     BPROCR  -BASE PROCUREMENT RATE
9975R DPROCR.KL=(DEOQ.K)(DFO.K)
10000NOTE     DPROCR  -DEPOT PROCUREMENT RATE
10025NOTE     DEOQ    -DEPOT ECONOMIC ORDER QUANTITY
10050NOTE     DFO     -DEPOT FRACTION ORDERED
```

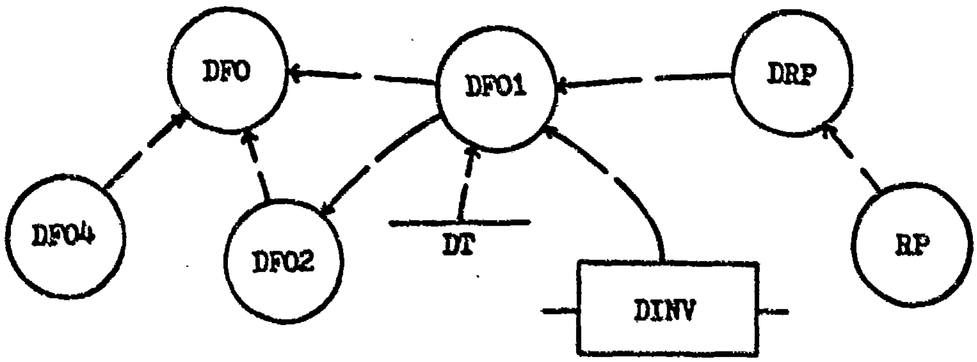
Figure 4-23. Depot Inventory Sector Diagram 1




```
10075A DEOQ.K=(5)(EOQ.K)
10100NOTE     DEOQ    -DEPOT ECONOMIC ORDER QUANTITY
10125NOTE     EOQ     -BASE ECONOMIC ORDER QUANTITY
```

Figure 4-24. Depot Inventory Sector Diagram 2

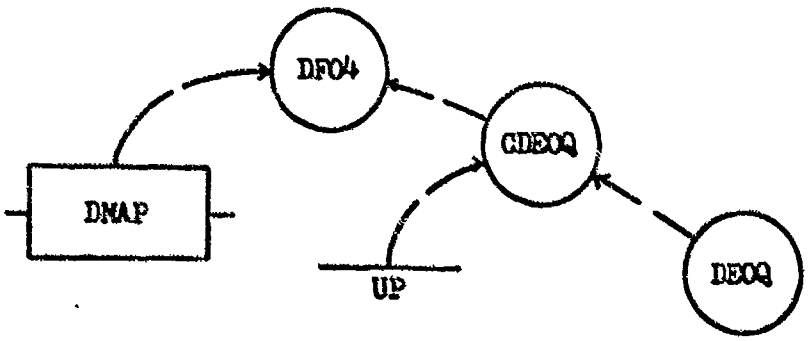
The Depot Fraction Ordered is the second factor that affects the Depot Procurement Rate in Figure 4-23. Figure 4-25 illustrates that it is composed of three factors: Depot Fraction Ordered factors 1,2, and 4. Factors 1 and 2 are timing factors that "order" parts for the Depot Inventory when the inventory level reaches the Depot Reorder Point. The Depot Reorder Point, like the Depot Economic Order Quantity, was set to equal five times the Base Reorder Point to ensure that the depot sector could always fill the demands of the base sector.




```
10150A DFO.K=(DFO1.K)(DFO2.K)(DFO4.K)
10175NOTE     DFO     -DEPOT FRACTION ORDERED
10200NOTE     DFO1    -DEPOT FRACTION ORDERED 1
10225NOTE     DFO2    -DEPOT FRACTION ORDERED 2
10250NOTE     DFO4    -DEPOT FRACTION ORDERED 4
10275A DFO1.K=CLIP(0,(1/DT),DINV.K,DRP.K)
10300NOTE     DFO1    -DEPOT FRACTION ORDERED 1
10325NOTE     DT      -DELTA TIME
10350NOTE     DINV    -DEPOT INVENTORY
10375NOTE     DRP     -DEPOT REORDER POINT
10400L DFO2.K=CLIP(0,1,DFO1.J,0.5)
10425NOTE     DFO2    -DEPOT FRACTION ORDERED 2
10450NOTE     DFO1    -DEPOT FRACTION ORDERED 1
10475A DRP.K=(5)(RP.K)
10500NOTE     DRP     -DEPOT REORDER POINT
10525NOTE     RP      -BASE REORDER POINT
```

Figure 4-25. Depot Inventory Sector Diagram 3

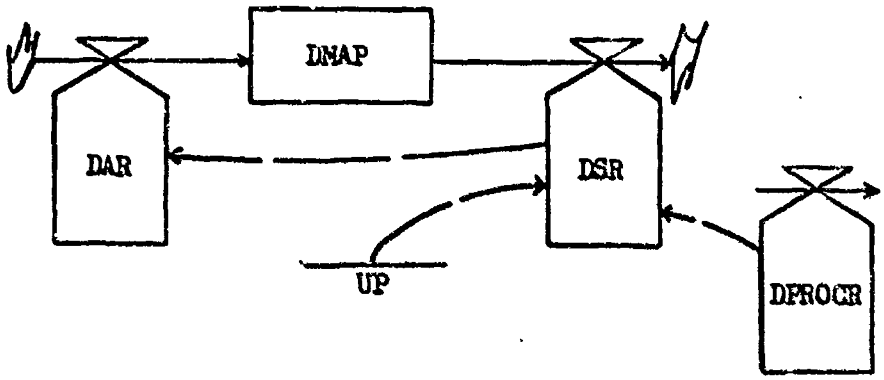
Figure 4-26 illustrates that the Depot Fraction Ordered factor 4 is a function of the Cost of the Depot Economic Order Quantity and the amount of money that the depot has available for the procurement of spare parts. Factor 4 limits the size of the order that the depot places with its vendors to the amount of money that it has available to spend. An implicit assumption of the Depot Fraction Ordered is that the depot's suppliers can always completely fill the depot's orders. The Cost of the Depot Economic Order Quantity is equal to the Depot Economic Order Quantity times the Unit Price of the item being procured.




```
10550A DFO4.K=CLIP(1,(DNAP.K/CDEOQ.K),(DNAP.K-CDEOQ.K),0)
10575NOTE     DFO4     -DEPOT FRACTION ORDERED 4
10600NOTE     DNAP     -DEPOT MONEY AVAILABLE FOR PROCUREMENT
10625NOTE     CDEOQ    -COST OF DEPOT ECONOMIC ORDER QUANTITY
10650A CDEOQ.K=(DEOQ.K)(UP)
10675NOTE     CDEOQ    -COST OF DEPOT ECONOMIC ORDER QUANTITY
10700NOTE     DEOQ     -DEPOT ECONOMIC ORDER QUANTITY
10725NOTE     UP       -UNIT PRICE
```

Figure 4-26. Depot Inventory Sector Diagram 4

Figure 4-27 illustrates the flow of money through the depot sector. The level of Depot Money Available for Procurement is a function of the Depot Appropriation Rate and the Depot Spending Rate. In order to insure that the depot always has adequate funds to purchase parts so that it can meet the base's demands, the Depot Appropriation Rate is set to equal the Depot Spending Rate. The Depot Spending Rate is a function of the Depot Procurement Rate and the Unit Price of the items purchased.



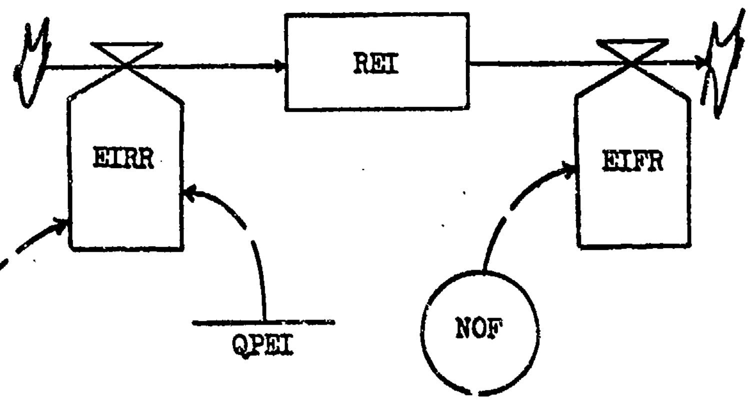

```
10750L DMAP.K=DMAP.J+(DT)(DAR.JK-DSR.JK)
10775NOTE     DMAP    -DEPOT MONEY AVAILABLE FOR PROCUREMENT
10800NOTE     DT      -DELTA TIME
10825NOTE     DAR     -DEPOT APPROPRIATION RATE
10850NOTE     DSR     -DEPOT SPENDING RATE
10875R DAR.KL=DSR.JK
10900NOTE     DAR     -DEPOT APPROPRIATION RATE
10925NOTE     DSR     -DEPOT SPENDING RATE
10950R DSR.KL=(DPROCR.JK)(UP)
10975NOTE     DSR     -DEPOT SPENDING RATE
11000NOTE     DPROCR  -DEPOT PROCUREMENT RATE
11025NOTE     UP      -UNIT PRICE
```

Figure 4-27. Depot Inventory Sector Diagram 5

This concludes the discussion of the Depot Inventory Sector. The next section discusses the consumption of parts by the base.

## Consumption Sector

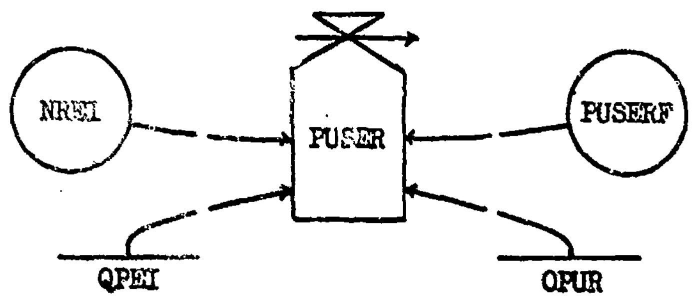
This sector discusses the factors that influence the use of spare parts by the base level organization. The number of Ready End Items is the central variable in this sector. Figure 4-28 illustrates that the number of Ready End Items is a function of the End Item Repair Rate and the End Item Failure Rate. The End Item Repair Rate is a function of the Parts Use Rate and the Quantity of Parts per End Item; the End Item Failure Rate is a function of the Number of Failures of the end item that are due to the component under study. The next several paragraphs discuss the factors that determine the Parts Use Rate.




```
11375L REI.K=REI.J+(DT)(EIRR.JK-EIFR.JK)
11400NOTE      REI     -READY END ITEMS
11425NOTE      DT      -DELTA TIME
11450NOTE      EIRR    -END ITEM REPAIR RATE
11475NOTE      EIFR    -END ITEM FAILURE RATE
11500R EIRR.KL=(PUSER.JK/QPEI)
11525NOTE      EIRR    -END ITEM REPAIR RATE
11550NOTE      PUSER   -PARTS USE RATE
11575NOTE      QPEI    -QUANTITY OF PARTS PER END ITEM
11600R EIFR.KL=NOF.K
11625NOTE      EIFR    -END ITEM FAILURE RATE
11650NOTE      NOF     -NUMBER OF FAILURES
```

Figure 4-28. Consumption Sector Diagram 1

Figure 4-29 illustrates that the Parts Use Rate is a function of four factors: the Quantity of Parts per End Item, the Parts Use Rate generated by weapon systems at the base other than the one under study, the number of Not Ready End Items due to malfunction of the component under study, and the Parts Use Rate Factor.

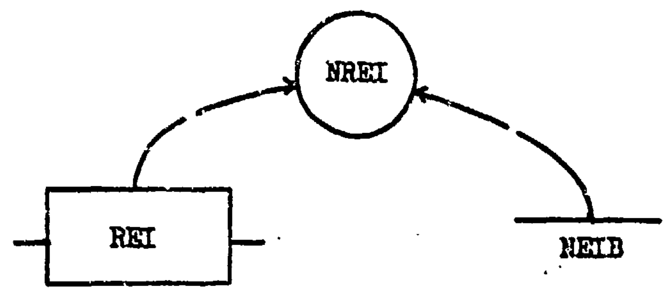



```
11675R PUSER.KL=(NREI.K)(QPEI)(PUSERF.K)+OPUR
11700NOTE     PUSER   -PARTS USE RATE
11725NOTE     NREI    -NOT READY END ITEMS
11750NOTE     QPEI    -QUANTITY OF PARTS PER END ITEM
11775NOTE     PUSERF  -PARTS USE RATE FACTOR
11800NOTE     OPUR    -OTHER PARTS USE RATE
```

Figure 4-29. Consumption Sector Diagram 2

The Quantity of Parts per End Item is a constant that is extracted from the weapon system provisioning document. It is the quantity of the particular part under study that is used each time an end item is repaired. The Other Parts Use Rate requirement is the total demand for the item at the base by all other weapon systems except the one that requires the ISSL.

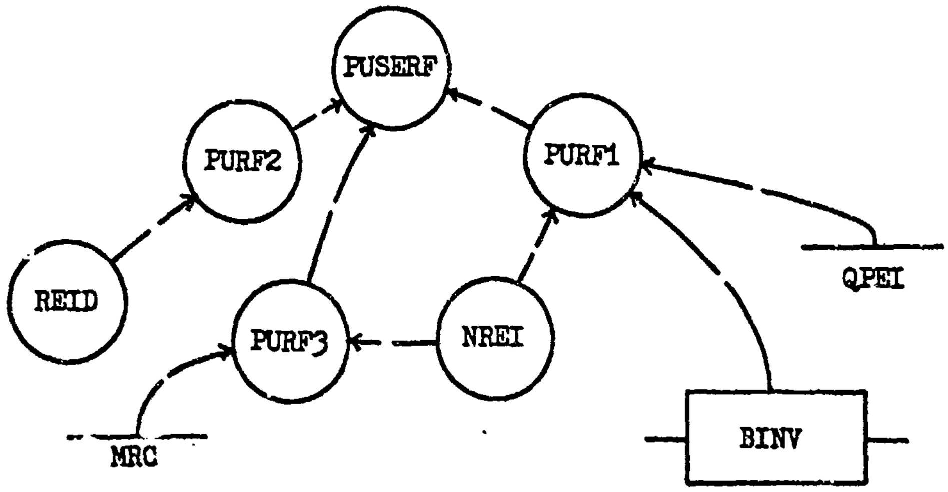
As illustrated in Figure 4-30, the number of Not Ready End Items is simply the difference between the Number of End Items on the Base and the number of Ready End Items.




```
11825A NREI.K=NEIB-REI.K
11850NOTE      NREI    -NOT READY END ITEMS
11875NOTE      NEIB    -NUMBER OF END ITEMS ON BASE
11900NOTE      REI     -READY END ITEMS
```

Figure 4-30. Consumption Sector Diagram 3

Figure 4-31 illustrates that the Parts Use Rate Factor is a function of three elements: Parts Use Rate Factors 1,2, and 3. Parts Use Rate Factor 1 limits the Parts Use Rate at the base to the number of parts that are available in the base inventory. Parts Use Rate Factor 2 is a table function that relates the amount of emphasis that is placed by the base on the repair of Not Ready End Items to the number of Not Ready End Items and the Required Number of Ready End Items. This relationship was developed intuitively and is plotted in Figure 4-32. It states that as the actual number of Ready End Items exceeds the required number of Ready End




```
11925A PUSERF.K=(MIN(PURF1.K,PURF3.K))(PURF2.K)
11950NOTE      PUSERF  -PARTS USE RATE FRACTION
11975NOTE      PURF1   -PARTS USE RATE FRACTION 1
12000NOTE      PURF3   -PARTS USE RATE FRACTION 3
12025NOTE      PURF2   -PARTS USE RATE FRACTION 2
12050A PURF1.K=CLIP(1,(BINV.K/(NREI.K)(QPEI)),(BINV.K-
12075X (NREI.K)(QPEI)),0)
12100NOTE      PURF1   -PARTS USE RATE FRACTION 1
12125NOTE      BINV    -BASE INVENTORY
12150NOTE      NREI    -NOT READY END ITEMS
12175NOTE      QPEI    -QUANTITY OF PARTS PER END ITEM
12200A PURF2.K=TABHL(PURF2T,REID.K,-10,1,1)
12225NOTE      PURF2   -PARTS USE RATE FRACTION 2
12250NOTE      PURF2T  -PARTS USE RATE FRACTION 2 TABLE
12275NOTE      REID    -READY END ITEM DISCREPANCY
12300A PURF3.K=CLIP(1,(MRC/NREI.K),(MRC-NREI.K),0)
12325NOTE      PURF3   -PARTS USE RATE FRACTION 3
12350NOTE      MRC     -MAINTENANCE REPAIR CAPABILITY
12375NOTE      NREI    -NOT READY END ITEMS
```

Figure 4-31. Consumption Sector Diagram 4

Items, there is less pressure at the base to repair the defective items. Conversely, it states that as the number of defective end items approaches or becomes less than the required number of end items, there is an increased effort placed on repairing the defective units. Parts Use Rate Factor 3 prevents the Parts Use Rate from exceeding the Maintenance Repair Capability of the organization (as determined by unit manning, facilities, tools, etc.).

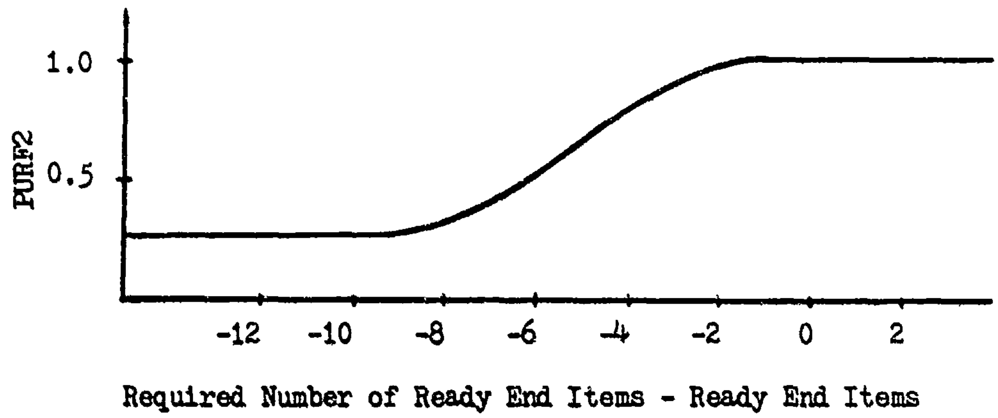
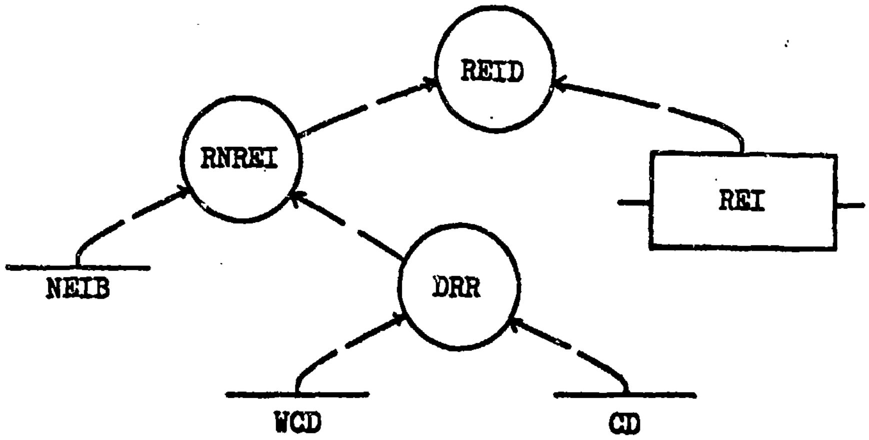



Figure 4-32. Parts Use Rate Factor 2 Graph

Figure 4-33 illustrates that the Ready End Item Discrepancy is the difference between the Required Number of Ready End Items and the actual number of Ready End Items. The Required Number of Ready End Items is simply the number of end items at the base multiplied by the Desired Ready Rate. The Desired Ready Rate is the ready rate



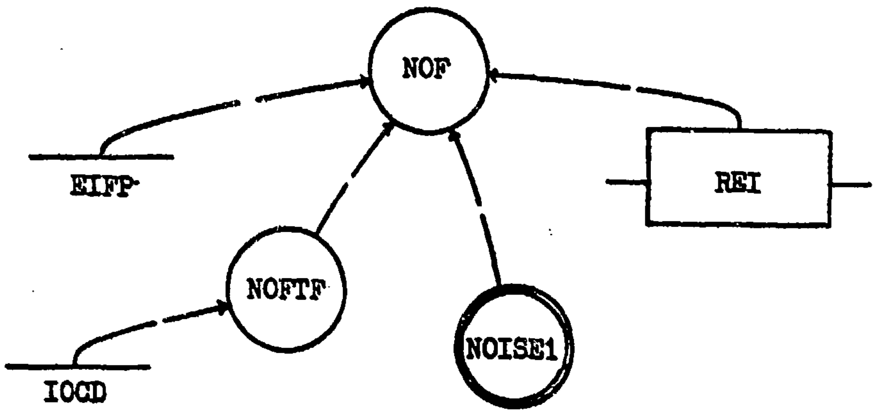

```
12400A REID.K=RNREI.K-REI.K
12425NOTE      REID    -READY END ITEM DISCREPANCY
12450NOTE      RNREI   -REQUIRED NUMBER OF READY END ITEMS
12475NOTE      REI     -READY END ITEMS
12500A RNREI.K=(DRR.K)(NEIB)
12525NOTE      RNREI   -REQUIRED NUMBER OF READY END ITEMS
12550NOTE      DRR     -DESIRED READY RATE
12575NOTE      NEIB    -NUMBER OF END ITEMS ON BASE
12600A DRR.K=CD+WCD
12625NOTE      DRR     -DESIRED READY RATE
12650NOTE      CD      -COMMAND DIRECTIVES
12675NOTE      WCD     -WING COMMANDER'S DESIRES
```

Figure 4-33. Consumption Sector Diagram 5

required by Command Directives as modified by the unit commander's desires.

This completes the discussion of the factors that influence the End Item Repair Rate and Parts Use Rate, the left-hand side of Figure 4-28. The next several paragraphs discuss the End Item Failure Rate, the right-hand side of Figure 4-28.

It was already stated that the End Item Failure Rate is a function of the Number of Failures of the end item that are due to the component under study. Figure 4-34 illustrates that the Number of Failures is a function of four factors: the number of Ready End Items, the timing factor, the End Item Failure Parameter, and a noise factor.




```
12700A NOF.K=(REI.K)(EIFP)(NOISE1.K)(NOFTF.K)
12725NOTE      NOF     -NUMBER OF FAILURES
12750NOTE      REI     -READY END ITEMS
12775NOTE      EIFP    -END ITEM FAILURE PARAMETER
12800NOTE      NOISE1  -NOISE 1
12825NOTE      NOFTF   -NUMBER OF FAILURES TIMING FACTOR
12850A NOFTF.K=STEP(1,IOCD)
12875NOTE      NOFTF   -NUMBER OF FAILURES TIMING FACTOR
12900NOTE      IOCD    -INITIAL OPERATION CAPABLE DATE
12925A NOISE1.K=NORMRN(1.0,0.2)
12950NOTE      NOISE1  -NOISE 1
```

Figure 4-34. Consumption Sector Diagram 6

The timing factor is a function of the Initial Operational Capable Date of the weapon system under study. It prevents the model from simulating any end item failures before that date, and after that date it permits the model to simulate the number of failures that are determined by the other three factors.

The End Item Failure Parameter is a constant that is dependent on such factors as weapon system operating environment, use rate, and mission profile. It was fully discussed in Chapter III.

The noise factor was added to the number of failure equation to simulate the random fluctuations in the number of failures that are due to factors that are not considered by the model.

This concludes the discussion of the flow diagrams and DYNAMO equations that were developed to permit computer simulation of the ISSL model. The chapter consisted of a variable-by-variable discussion of all four sectors of the model. It identified all the variables in the model and discussed the mathematical relationships among them. Chapter V addresses the validity of these hypothesized relationships and the parameters that were used to run the model on the computer.

## Chapter V

## MODEL VALIDATION

### Introduction

In his book Industrial Dynamics Jay Forrester stated that model validity ". . . depends on how well it [the model] serves its purpose [3:115]." He continued to say that a model ". . . should be judged by its suitability for a particular purpose. A model is sound and defendable if it accomplishes what is expected of it [3:115]." Therefore, the model which was constructed is valid if it fulfills the objectives established by the analysts at the beginning of the research effort.

The importance of establishing objectives in model development and validation were stated by Forrester when he said:

> . . . the absolute worth of a model can be no greater than the worth of its objectives.
>
> The value of the objective trancends all other considerations in determining the utility of a model [3:116].

Therefore, the analyst must choose an objective which is significant. In order to choose a significant objective the analyst must have a ". . . keen perception of symptoms [of system behavior] and, ability to relate them to the probable causes [3:116]." For this research effort, the objective of the model was to simulate the process involved in the development of the initial spares support list (ISSL).

Through the construction of a valid model which satisfies the research objectives, the Air Force will be provided with a device to be used in reaching a decision concerning initial provisioning; i.e., ISSL quantity decisions.

With the establishment of significant and meaningful objectives the effectiveness of the model must be established. Model effectiveness depends ". . . first on the system boundaries it encompasses, second on the pertinence of selected variables, and last on the numerical values of the parameters [3:115-117]." In determining the effectiveness of the model, confidence is developed in the model. This chapter examines the dynamic model of the ISSL development process to determine its validity in terms of the boundaries established for the system, the interaction of the variables identified as components of the system, and finally the results obtained from the values assigned as the model parameters.

## System Boundaries

Establishing the system boundaries is the ". . . first and most important question about detailed model design . . .[3:117]" which must be answered. The selection of system boundaries is directly related to the objectives that are established by the analyst because they guide the study of the system in question. Forrester noted the importance of establishing sound system objectives and boundaries when he said:

> . . . Suitable boundaries are related to objectives. . . . If the boundaries range unnecessarily far, the model will be distracting and may lead to such confusion that the project is abandoned [3:117].

Applying these principles delineated by Forrester, the ISSL development process was conceptualized as being composed of four interdependent sectors, with each sector consisting of several variables. The interactivity of the variables and the interdependence of the sectors was discussed in Chapter III.

The variables within a given sector aggregated information and resources independent of the activity of another given sector. Therefore, each sector was free to act upon the information and resources based upon its own internal decision structure. From this independence of action it was concluded that the system boundaries were properly conceptualized and established correctly for the model of the ISSL development process. Once the system boundaries were established a check had to be performed to ensure that all pertinent variables and their proper interrelationships were included as part of the model.

## Pertinence of Selected Variables

After establishing the boundaries of the system the next step was to identify the variables which interact within these boundaries to form the model of the system. Forrester pointed out the significance of variable identification when he said

> The second most important question of model design is to ask if the model contains an effective choice of variables, properly interconnected. . . . Failure to include the proper system variables in a model can destroy the utility of the model as a design tool [3:118].

In determining and establishing the variables which are contained within a system the ". . . most difficult choices will be in the decision functions of the model [3:118]," because these variables ". . . exist largely within the information networks where policies are informal [3:118]." Hence, the model was constructed from the interacting variables, which were derived from the current information policies.

For the most part the current policy guidance was contained in the assorted Department of Defense; Headquarters, Air Force; and Headquarters, Air Force Logistics Command directives and regulations governing the actions and activities which comprise the initial spares support list development process. Thus, the variables which form the formal portion of the ISSL development process were somewhat easily discerned. However, in order for the model to accurately replicate the current system's structure the informal policy variables had to be included as well.

The informal policy variables were discerned from interviews with specialists responsible for the computations and adjustments made to the range and depth of support/replacement items included on the ISSL. These informal policy variables were combined with the formal policy variables and together they made up the causal-loop diagrams discussed in chapter III. From the research into the formal and informal policy formulation process the relationships that exist between the variables in each sector and the interdependence between the sectors were identified. This research into the variables also revealed that the model did conform to the actions and activities which combine to form the initial spares support list (ISSL) development process.

With the system boundaries established and the interacting variables identified the next action was to test the interaction of the variables to verify the resonableness of the model. Prior to testing the variable interaction values were assigned to initiate model activity.

Parameter Values

Having determined that the system boundaries were properly established and that all pertinent variables had been captured by these boundaries it was time to perform the third model validity check, which was to assign numerical values to the parameters within which the model will operate. The assignment of these parameter values was also discussed by Forrester when he said

> The third and least important aspect of a model to be considered in judging its validity concerns the values for its parameters. . . They may be chosen anywhere within a plausible range [3:119].

Forrester considered the parameters chosen for the numerical values of the variables to be least important because of the sensitivity of the variables. Forrester noted that a few variables will be insensitive to the values assigned; however, a ". . . few sensitive parameters will be identified by model tests. . . [3:119]."

Since this research effort was directed towards the development of a model of initial spares support for new items coming into the Air Force inventory, standard values were assigned to many of the variables. For the most part these standard values are contained within the governing directives and regulations. These standard values are applicable to the ISSL Development Sector and are used in conjunction with the computation parameters established by the equipment specialist to determine the initial spare/replacement parts quantity level.

The other parameters that have an impact on the variables which make up the ISSL development process are those established by the using Major Command. The using command establishes the number of end items to be assigned to the base and the mission profiles for the end item which are the parameters with the greatest impact on the remaining three sectors of Base Inventory, Depot Inventory, and Consumption, as the demand levels for the spare/replacement parts are projected based on anticipated end item usage.

With the three phases of model validity established by Forrester satisfied, the remaining task was to reproduce system behavior by simulation. The reproduction of system behavior through model simulation is the subject of the final section of this chapter.

Reproducing System Behavior

The true test of how well the analyst designed his model to represent the system under study is demonstrated when the model is utilized. Once again it was Forrester who provided the insight into the importance of the model duplicating the system when he said the model

> . . . should generate time patterns of behavior that do not differ in any significant way (judged within the framework of the objectives of the study) from the real system. . . . the more indistinguishable the over-all model performance is from a typical history of the actual system, the better our confidence in the model is apt to be [3:119].

Using these guidelines it was assumed that the value of the ISSL development process model would be shown in the model's ability to represent the behavior of the real system.

In order to verify the model's ability to simulate the performance of the ISSL development process, a hypothetical situation was created. Input values were developed based on information obtained during the research effort. These values were input into the model, and the model was run on the computer. The results of the simulation for selected variables are shown in the following figures.

Figure 5-1 illustrates the model's ability to generate the Base Inventory level pattern that is consistent with the Parts Use

Figure 5-2 illustrates the model's capability to simulate the adjustment of the Established Base Inventory Level. The Established Base Inventory Level is adjusted when orders are placed until the level reaches a value that is in equilibrium with the Parts Use Rate. As was discussed in Chapters III and IV, adjustments can be made to the Base Inventory level only if the magnitude of the adjustment meets certain criteria that are specified in Air Force directives.

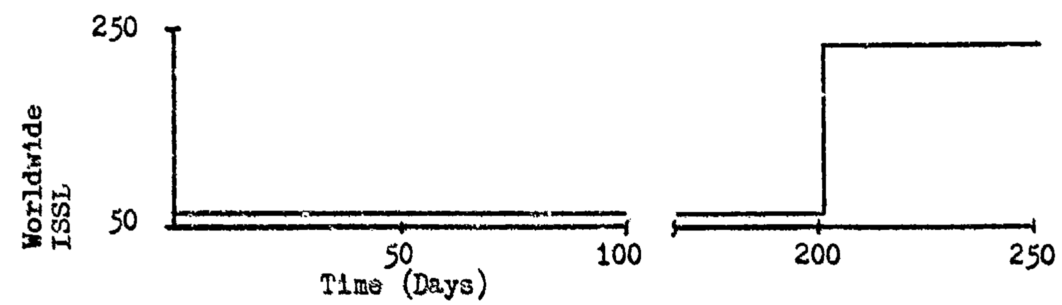



Figure 5-3. Simulation Results Graph 3

Figure 5-3 illustrates that the model simulates the adjustments of the Worldwide ISSL level at the Worldwide ISSL Review Time. At the review time the Worldwide ISSL level is adjusted, if required, to make it consistent with actual parts consumption data that has been generated by using organizations.

During the course of research into the validity of the model, varying lengths of simulation and different parameter values were input into the system. In all cases similar results were obtained. Thus the model demonstrated its ability to stabilize and adjust quantity levels based on actual demand generated from actual parts use rate. Therefore, it was concluded that the system boundaries were properly established, the pertinent variables had been included in the model design, and the numerical values assigned as the variable parameters were accurate. Since all three validity factors were satisfied, the model appears to be valid and capable of reproducing expected system behavior.

The foregoing served to verify the internal validity of the model; i.e., it demonstrated to the authors that the model simulates the behavior of the ISSL development process as they conceptualized the system to be. Verification of the external validity of the model, i.e., that the model actually simulates the behavior of the real-world system, requires the input of actual historical data.

A summary of the research effort, recommendations for further study, and the conclusions that were drawn from the research project are the subjects of the next chapter.

## Chapter VI

## SUMMARY, RECOMMENDATIONS, AND CONCLUSIONS

Six objectives were established at the beginning of this project. A summary of the research effort is presented by addressing how well each of the objectives was accomplished. The summary is followed by recommendations for further study and the conclusions that were reached as a result of the study.

### Summary

Dynamic Interrelationships. The first objective of this research was to determine pertinent dynamic interrelationships that comprise the ISSL development process. This was a three step process that involved setting the boundaries of the system, identifying pertinent variables, and determining the relationships among them. This was successfully accomplished and permitted investigation of the cause and effect relationships.

Cause and Effect. The second research objective was to trace the cause and effect of the relationships among the variables of the system. Causal loop analysis, as described in Chapters II and III, was used to logically investigate the specific nature of the relationships of the ISSL development process. This analysis led to investigation of the system's control process.

Control Process Formulation. Description of how decisions resulted from available information streams, through formulation of the control process of the system was the third research objective. This objective was accomplished by creating the sector flow diagrams that were presented in Chapter IV. The flow diagrams formally identified the decision points, information flows, and resource flows within the ISSL development process. Completion of the system flow diagrams permitted the construction of a mathematical model of the system.

Construction of the Mathematical Model. The fourth research objective was to construct a mathematical model of the ISSL development process. The DYNAMO simulation language was used as the framework for model construction. The model was completed using the flow diagrams that were presented in Chapter IV as an outline. Parameters were extracted from currently available data sources or intuitively developed. Completion of the mathematical model made it possible to simulate the behavior of the hypothetical ISSL development process.

Simulation of Behavior. The fifth objective of the research was to operate the model. Each operation of the model generated one simulation of the system. Numerous simulations were accomplished and, after each simulation, the model behavior was analyzed to determine if the expected behavior was present. If, in fact, it was not, the model was analyzed to determine the cause of the unexpected behavior. Once the cause was discovered, the model was modified and the simulation repeated. This iterative process led to internal validation of the model.

Validation Testing. The final objective of the research was to test the validity of the model with historical data. As outlined in Chapter V, validation is twofold: internal and external. The internal validity of the model was demonstrated by the system behavior patterns that the model generated for the values of the parameters that were used during numerous simulations. External validation of the model was prevented due to a lack of historical parts consumption data and the inability to measure the human factors that influence the inputs to the ISSL development process. Until this information is developed, full model validation is impossible. Partly as a result of this inability to externally validate the model, recommendations for further study have been formulated.

## Recommendations for Further Study

The authors feel that four areas need further research. First, the model that was developed in the project needs to be externally validated. Real world data needs to be collected, inserted into the model, and the model run to ensure that it indeed accurately simulates the behavior of the ISSL development process.

During the course of the research project, it was discovered that ISSL reviews are kept to an absolute minimum and that the accuracy of the actual parts consumption data that is available for use during these ISSL review meetings is, at best, questionable. The second recommendation is that the model be used to investigate the effectiveness of various ISSL review policies and to determine the sensitivity of the system to the inaccurate data that is used in the ISSL review process.

Also discovered during the course of the research was the fact that the base level ISSL is prorated from the worldwide ISSL based on the fraction of the total number of end items that the base receives and the projected end item use rate. No consideration is given to the different environmental conditions that exist at different bases. By not considering the end item operating environment, one base may be overstocked with an item whereas another base may be understocked. This leads to the third recommendation: the model should be used to investigate the effects of considering environmental variables on the effectiveness of the base level ISSL.

The last recommendation follows from the stock level imbalances that were just described. It is more general and is beyond the scope of the present model. The authors recommend that other ISSL distribution policies be investigated. During the course of the research, three options were discussed with various AFLC officials: contractor provided support, regional ISSLs, and centralized support.

Under the contractor provided support option, the contractor would provide the initial support for an end item for a designated period of time. Then, based on actual parts consumption data, the stock levels required for system support would be determined. By using actual data, predicting future needs for support becomes more precise and funds for procurement can be spent more effectively and efficiently. Also, more accurate ISSLs could be developed that would provide better support to base level units.

The regional ISSL concept would be predicated on the anticipated operating environment in the area that the weapon system is to be employed. Under this concept the effect of different environments on end item failure rates would have to be determined and the projected support requirements for each environment calculated. To illustrate this point, tests might show that more failures occur in a hot, humid environment than in a more temperate environment; thus, more parts would be required in the hot, humid region. Under this concept, a larger portion of the worldwide ISSL would be given to bases in the hot, humid areas than in the temperate areas. Prior to adopting this concept, the costs of conducting the environmental tests should be compared to the anticipated benefits of the concept; however, the regional concept has the potential of providing more effective and efficient ISSLs.

The centralized support concept is an extention of the regional ISSL concept. Under this concept, a single base within a given region would be designated as the central supply point for system support. This base would maintain the ISSL inventory for the region and would ship items to customer bases on an as-required basis. This procedure would have the effect of smoothing demand and would improve efficiency by minimizing the problem of one base being "overstocked" while another was "understocked."

## Conclusions

Two conclusions can be drawn from this project. First, it is possible to develop a mathematical model that simulates the management and decision structures that constitute the ISSL development process. If this model is validated with real world data, it could become a very useful tool for improving the ISSL development process.

The second conclusion is that the present ISSL development process is not efficiently supporting Air Force weapon systems. In many cases too many, too few, or the incorrect spare parts are procured. This results in either needless expenditure of funds or unnecessary equipment down time. There appear to be two reasons for this inefficiency.

The first reason is that AFLC is using a piecemeal approach for providing end item support. While all parties involved seek to provide adequate support, there is no one person who oversees the entire process. For example, all of the inventory management specialists that were interviewed were knowledgable in their own individual areas and had a working knowledge of an Air Logistics Center, but none of them had a complete picture of ISSL development.

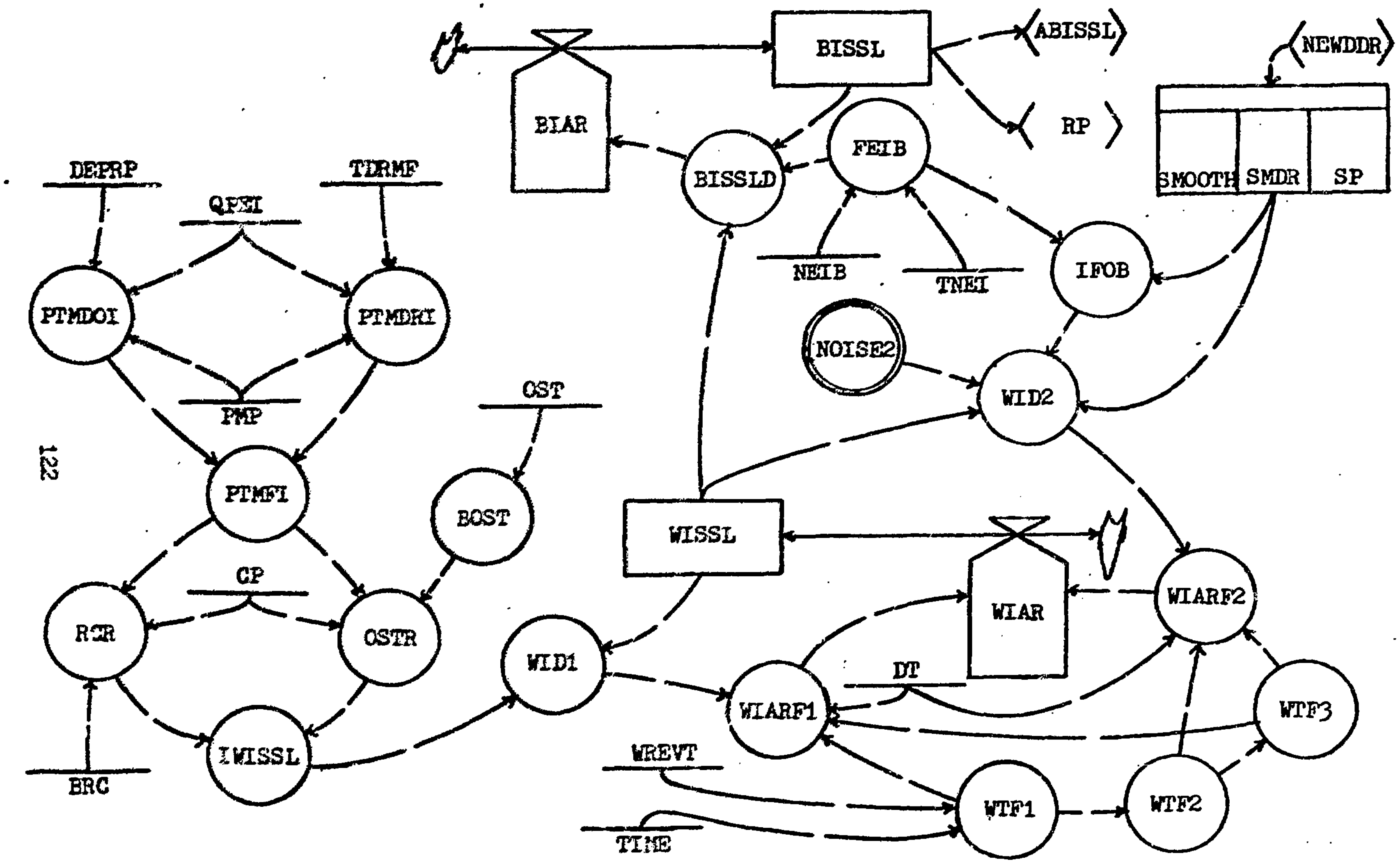
A second reason for the inefficiency appears to be an over dependence on the computer. While the computer does provide a valuable service in management, care must be taken to make sure that the managers understand and maintain control over their system. The analysts discovered two cases in which the computer is "controlling" the managers. First, AFLC has developed a program to provide the headquarters with information about parts use rates so that ISSL levels can be adjusted. This program is not working because of a computer interface problem that requires manual recoding of data. Because the managers in the ALCs do not have the time to recode the data, i.e., to properly "feed" the computer, the data is lost, and the program thus far has not worked. The second case that the analysts discovered was in the local base supply activity. The managers that were interviewed there relied entirely on the computer to calculate their reorder points and reorder quanties; they had no idea what kind of calculations the computer used to determine the numbers that they use to manage their system.

If a manager is to make his organization both effective and efficient, he must be able to control it. In order for him to control his organization, he must be aware of the variables that influence the behavior of his system and he must understand how those variables interact to produce the behavior of the system. Perhaps the greatest value of the model that was developed for this project is that it can provide a means to gain that understanding for the complex set of interactions that make up the ISSL development process.

APPENDICES

APPENDIX A

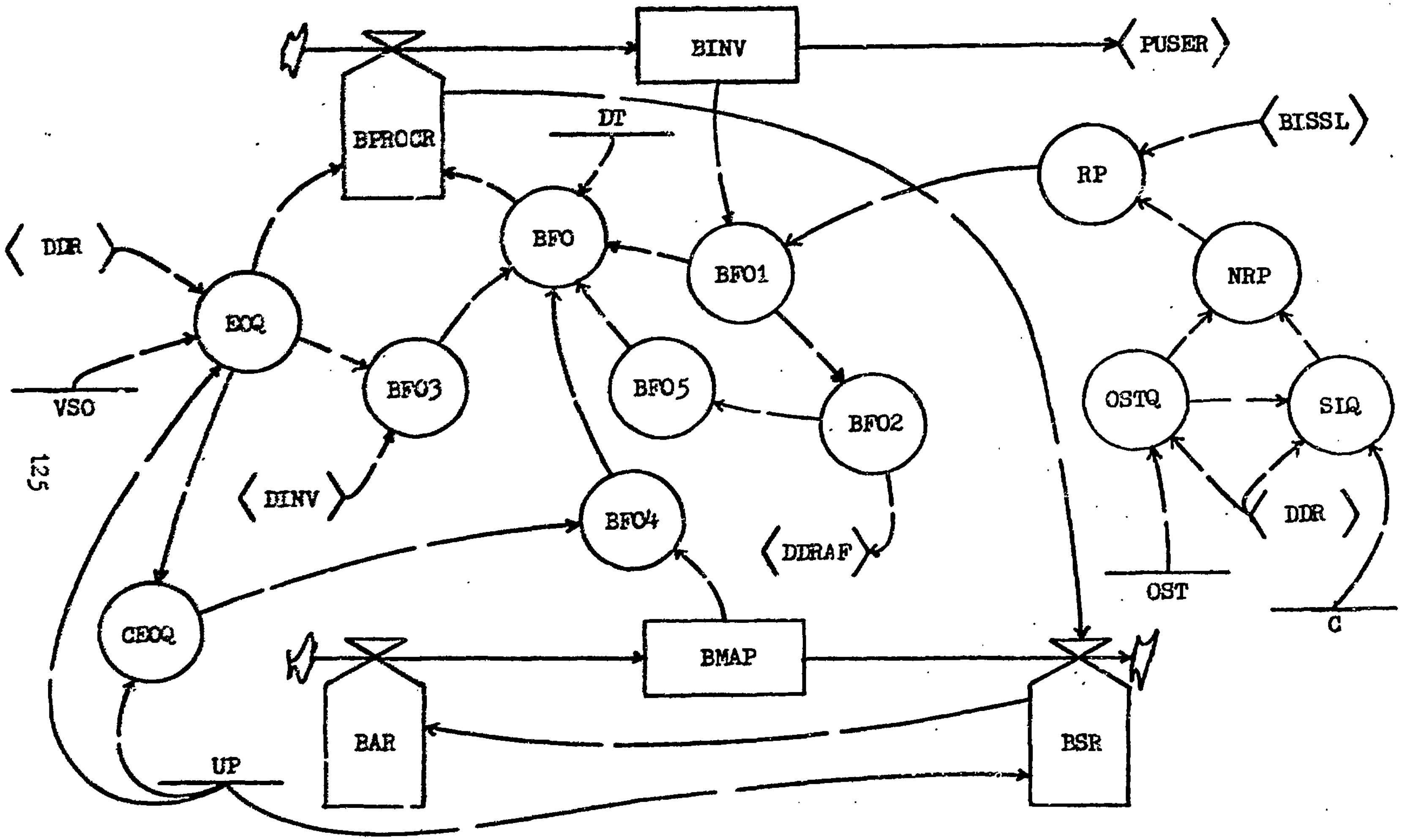
ISSL DEVELOPMENT SECTOR FLOW DIAGRAM AND VARIABLE LIST


BISSL
ABISSL
RP
NEWDDR
SMOOTH
SMDR
SP
BIAR
BISSLD
FEIB
NEIB
TNEI
IFOB
NOISE2
WID2
DEPRP
TDRMF
QPEI
PTMDOI
PTMDRI
PMP
PTMFI
OST
BOST
CP
OSTR
BRC
IWISSL
WISSL
WIAR
WIARF2
WID1
WIARF1
DT
WTF3
WREVT
TIME
WTF1
WTF2

```
C*************************************************************************
C
C VARIABLE LIST FOR THE ISSL DEVELOPMENT SECTOR
C
C ABISSL  ADJUSTED BASE ISSL
C BIAR    BASE ISSL ADJUSTMENT RATE
C BISSL   BASE ISSL
C BISSLD  BASE ISSL DISCREPANCY
C BRC     BASE REPAIR CYCLE
C BOST    BASE ORDER AND SHIP TIME
C CP      CONDEMNATION PERCENT
C DEPRP   DEPOT REPLACEMENT PERCENT
C DT      DELTA TIME
C FEIB    FRACTION OF END ITEMS ON BASE
C IFOB    INPUT FROM OTHER BASES
C IWISSL  INITIAL WORLDWIDE ISSL
C NEIB    NUMBER OF END ITEMS ON BASE
C NEWDDR  NEW DAILY DEMAND RATE
C NOISE2  NOISE 2
C OST     ORDER AND SHIP TIME
C OSTR    ORDER AND SHIP TIME REQUIREMENT
C PMP     PEAK MONTH PROGRAM
C PTMDOI  PEAK TOTAL MONTH DEPOT OVERHAUL ISSUES
C PTMDRI  PEAK TOTAL MONTH DEMAND RATE ISSUES
C PTMFI   PEAK TOTAL MONTH FIELD ISSUES
C QPEI    QUANTITY OF PARTS PER END ITEM
C RCR     REPAIR CYCLE REQUIREMENT
C RP      BASE REORDER POINT
C SMDR    SMOOTHED MONTHLY DEMAND RATE
C SP      SMOOTHING PERIOD
C TDRMF   TOTAL DEMAND RATE MAINTENANCE FACTOR
C TIME    TIME
C TNEI    TOTAL NUMBER OF END ITEMS
C WIAR    WORLDWIDE ISSL ADJUSTMENT RATE
C WIARF1  WORLDWIDE ISSL ADJUSTMENT RATE FACTOR 1
C WIARF2  WORLDWIDE ISSL ADJUSTMENT RATE FACTOR 2
C WID1    WORLDWIDE ISSL DISCREPANCY 1
C WID2    WORLDWIDE ISSL DISCREPANCY 2
C WISSL   WORLDWIDE ISSL
C WTF1    WORLDWIDE ISSL TIMING FACTOR 1
C WTF2    WORLDWIDE ISSL TIMING FACTOR 2
C WTF3    WORLDWIDE ISSL TIMING FACTOR 3
C WREVT   WORLDWIDE ISSL REVIEW TIME
C
C*************************************************************************
```

APPENDIX B

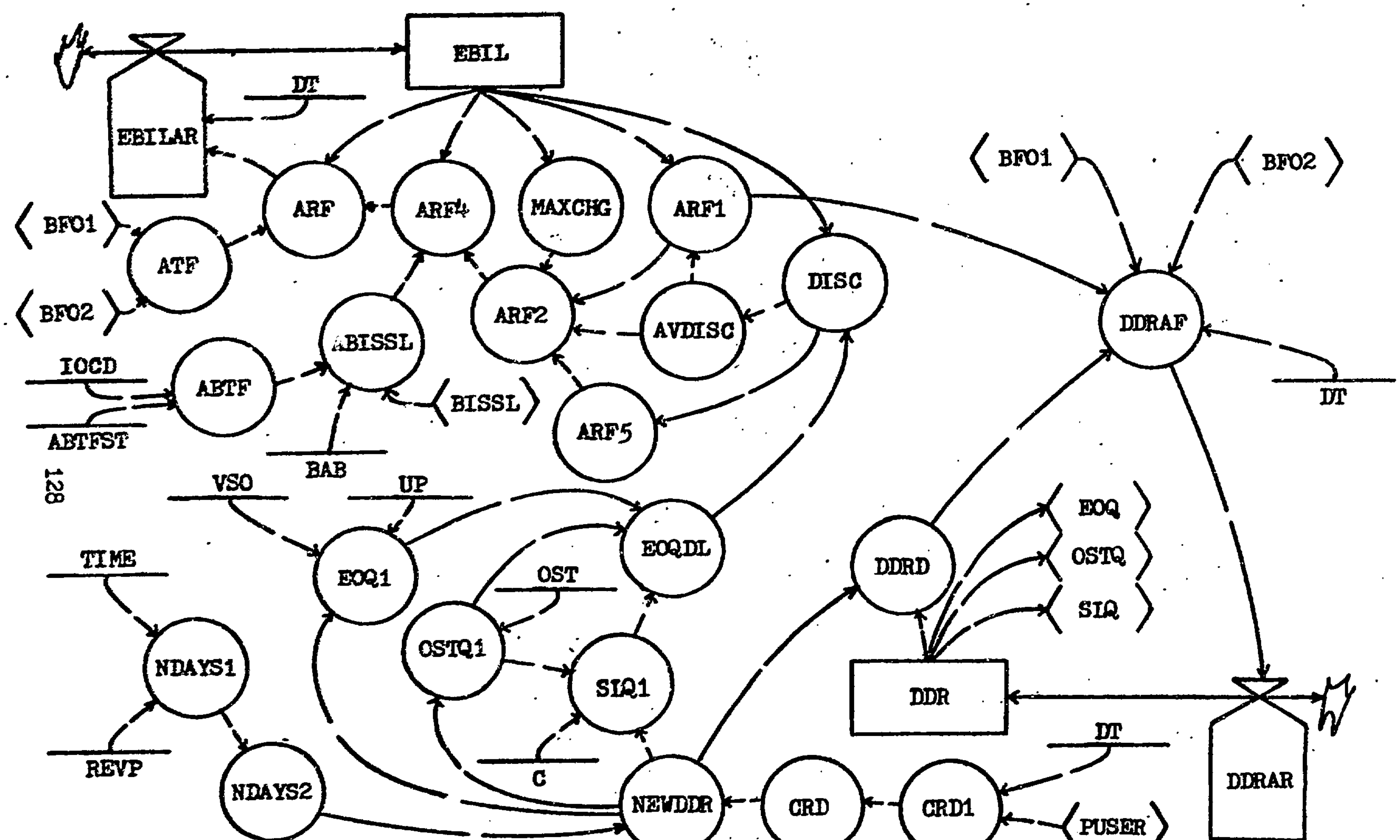
BASE INVENTORY SUBSECTOR FLOW DIAGRAM AND VARIABLE LIST


BINV
PUSER
BISSL
BPROCR
DT
RP
DDR
BFO
BFO1
NRP
EOQ
BFO3
BFO5
BFO2
OSTQ
SIQ
VSO
DINV
BFO4
DDR
DIRAF
OST
C
CEOQ
BMAP
BAR
BSR
UP

```
25C***************************************************************************
50C
75C VARIABLE LIST FOR THE BASE INVENTORY SUBSECTOR
100C
125C BAR     BASE APPROPRIATION RATE
150C BFO     BASE FRACTION ORDERED
175C BFO1    BASE FRACTION ORDERED 1
200C BFO2    BASE FRACTION ORDERED 2
225C BFO3    BASE FRACTION ORDERED 3
250C BFO4    BASE FRACTION ORDERED 4
275C BFO5    BASE FRACTION ORDERED 5
300C BINV    BASE INVENTORY
325C BISSL   BASE ISSL
350C BMAP    BASE MONEY AVAILABLE FOR PROCUREMENT
375C BPROCR  BASE PROCUREMENT RATE
400C BSR     BASE SPENDING RATE
425C C       CONSTANT
450C CEOQ    COST OF BASE ECONOMIC ORDER QUANTITY
475C DDR     DAILY DEMAND RATE
500C DDRAF   DAILY DEMAND RATE ADJUSTMENT FACTOR
525C DINV    DEPOT INVENTORY
550C DT      DELTA TIME
575C EOQ     BASE ECONOMIC ORDER QUANTITY
600C NRP     NORMAL REORDER POINT
625C OST     ORDER AND SHIP TIME
650C OSTQ    ORDER AND SHIP TIME QUANTITY
675C PUSER   PARTS USE RATE
700C RP      BASE REORDER POINT
725C SLQ     SAFETY LEVEL QUANTITY
750C UP      UNIT PRICE
775C VSO     VARIABLE STOCKAGE OBJECTIVE
800C
825C***************************************************************************
```

# APPENDIX C

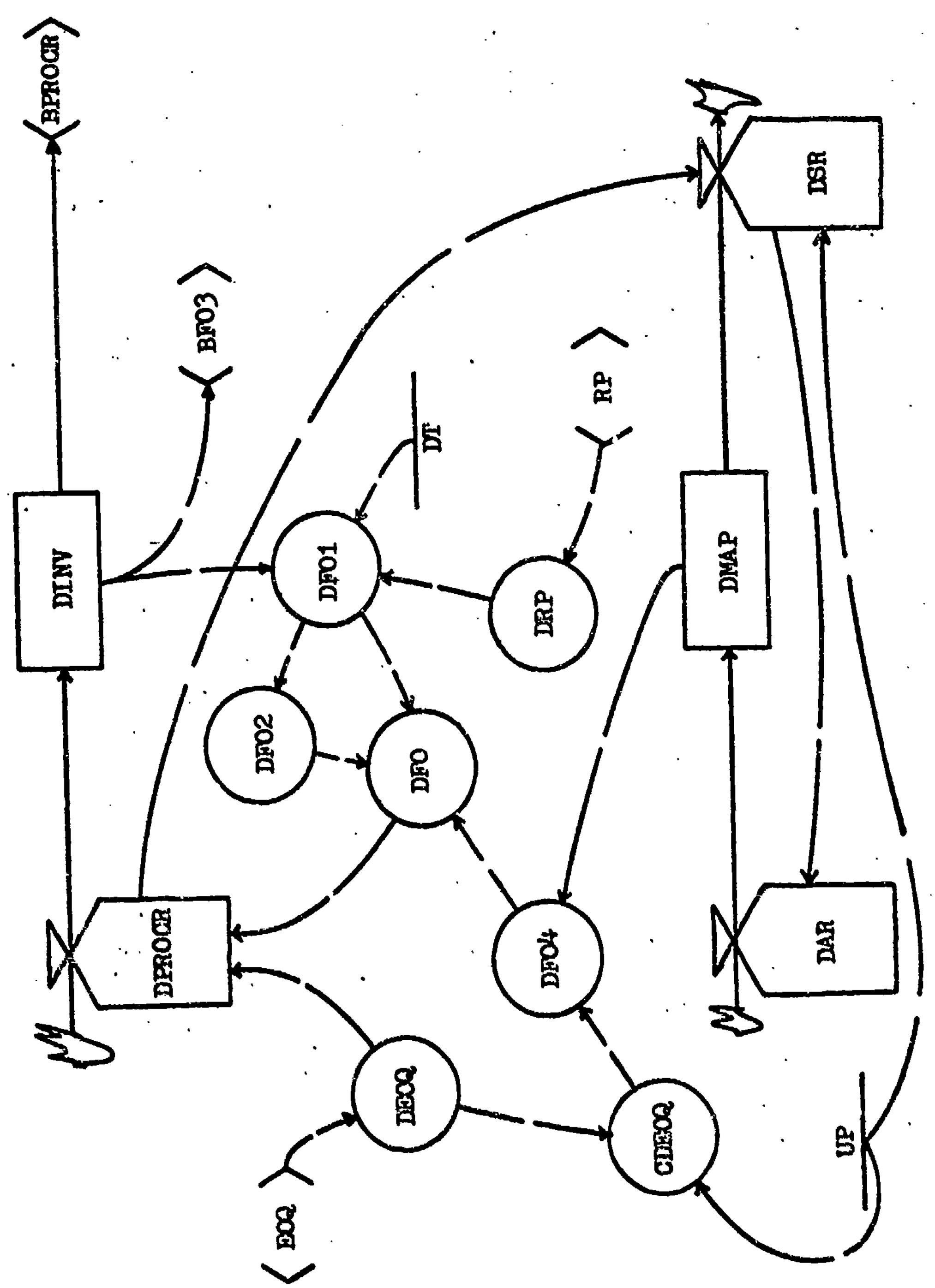
# DAILY DEMAND RATE ADJUSTMENT SUBSECTOR FLOW DIAGRAM AND VARIABLE LIST


EBIL
EBILAR
DT
ARF
ARF4
MAXCHG
ARF1
DISC
BFO1
BFO2
ATF
ARF2
AVDISC
ABISSL
ABTF
IOCD
ABTFST
BISSL
BAB
ARF5
DDRAF
DT
VSO
UP
EOQ1
EOQDL
TIME
NDAYS1
REVP
NDAYS2
OST
OSTQ1
SIQ1
C
NEWDDR
CRD
CRD1
DT
PUSER
DDRD
DDR
EOQ
OSTQ
SIQ
DDRAR

```
C************************************************************************
C
C VARIABLE LIST FOR THE DAILY DEMAND RATE ADJUSTMENT SUBSECTOR
C
C ABISSL  ADJUSTED BASE ISSL
C ABTF    ADJUSTED BASE ISSL TIMING FACTOR
C ABTFST  ABTF STEP TIME
C ARF     ADJUSTMENT RATE FACTOR
C ARF1    ADJUSTMENT RATE FACTOR 1
C ARF2    ADJUSTMENT RATE FACTOR 2
C ARF4    ADJUSTMENT RATE FACTOR 4
C ARF5    ADJUSTMENT RATE FACTOR 5
C ATF     ADJUSTMENT TIMING FACTOR
C AVDISC  ABSOLUTE VALUE OF DISC
C BAB     BASE ADJUSTMENT TO THE BASE ISSL
C BFO1    BASE FRACTION ORDERED 1
C BFO2    BASE FRACTION ORDERED 2
C BISSL   BASE ISSL
C C       CONSTANT
C CRD     CUMULATIVE RECURRING DEMAND
C CRD1    CUMULATIVE RECURRING DEMAND 1
C DDR     DAILY DEMAND RATE
C DDRAF   DAILY DEMAND RATE ADJUSTMENT FACTOR
C DDRAR   DAILY DEMAND RATE ADJUSTMENT RATE
C DDRD    DAILY DEMAND RATE DISCREPANCY
C DISC    DISCREPANCY
C DT      DELTA TIME
C EBIL    ESTABLISHED BASE INVENTORY LEVEL
C EBILAR  EBIL ADJUSTMENT RATE
C EOQ     BASE ECONOMIC ORDER QUANTITY
C EOQDL   BASE EOQ DEMAND LEVEL
C EOQ1    BASE ECONOMIC ORDER QUANTITY 1
C IOCD    INITIAL OPERATION CAPABLE DATE
C MAXCHG  MAXIMUM CHANGE
C NDAYS1  NUMBER OF DAYS 1
C NDAYS2  NUMBER OF DAYS 2
C NEWDDR  NEW DAILY DEMAND RATE
C OST     ORDER AND SHIP TIME
C OSTQ    ORDER AND SHIP TIME QUANTITY
C OSTQ1    ORDER AND SHIP TIME QUANTITY 1
C PUSER    PARTS USE RATE
C REVP     REVIEW PERIOD
C SLQ      SAFETY LEVEL QUANTITY
C SLQ1     SAFETY LEVEL QUANTITY 1
C TIME     TIME
C UP       UNIT PRICE
C VSO      VARIABLE STOCKAGE OBJECTIVE
C
C************************************************************************
```

APPENDIX D

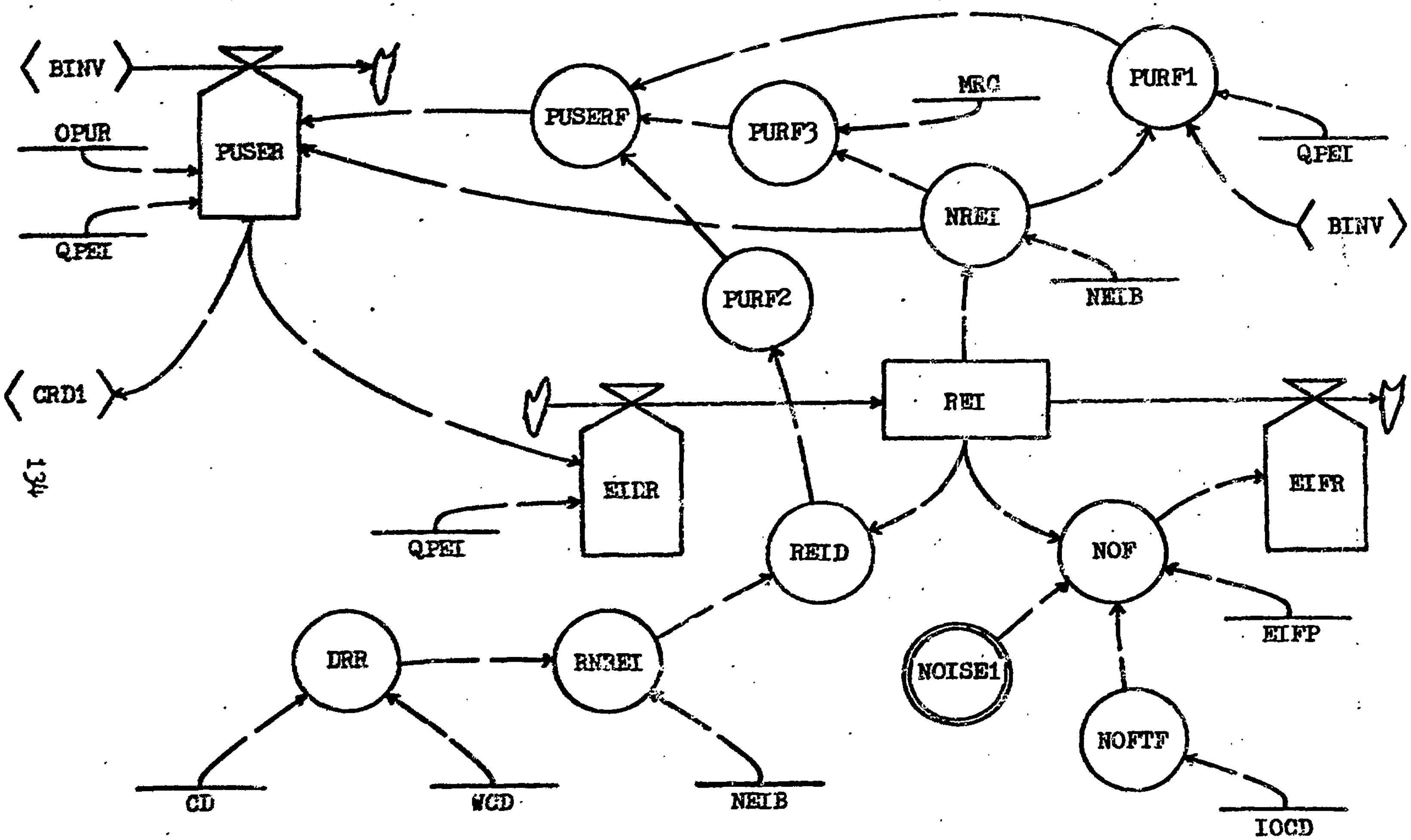
DEPOT INVENTORY SECTOR FLOW DIAGRAM AND VARIABLE LIST


BPROCR
BFO3
DT
RP
DINV
DFO1
DRP
DMAP
DSR
DFO2
DFO
DPROCR
DFO4
DAR
DEOQ
CDEOQ
EOQ
UP

```
25C************************************************************************
50C
75C VARIABLE LIST FOR THE DEPOT INVENTORY SECTOR
100C
125C BFO3    BASE FRACTION ORDERED 3
150C BPROCR  BASE PROCUREMENT RATE
175C CDEOQ   COST OF DEPOT ECONOMIC ORDER QUANTITY
200C DAR     DEPOT APPROPRIATION RATE
225C DEOQ    DEPOT ECONOMIC ORDER QUANTITY
250C DFO     DEPOT FRACTION ORDERED
275C DFO1    DEPOT FRACTION ORDERED 1
300C DFO2    DEPOT FRACTION ORDERED 2
325C DFO4    DEPOT FRACTION ORDERED 4
350C DINV    DEPOT INVENTORY
375C DMAP    DEPOT MONEY AVAILABLE FOR PROCUREMENT
400C DPROCR  DEPOT PROCUREMENT RATE
425C DRP     DEPOT REORDER POINT
450C DSR     DEPOT SPENDING RATE
475C DT      DELTA TIME
500C EOQ     BASE ECONOMIC ORDER QUANTITY
525C RP      BASE REORDER POINT
550C UP      UNIT PRICE
575C
600C************************************************************************
```

# APPENDIX E

# CONSUMPTION SECTOR FLOW DIAGRAM AND VARIABLE LIST


BINV
OPUR
QPEI
PUSER
CRD1
PUSERF
PURF3
MRC
PURF1
QPEI
BINV
NREI
NEIB
PURF2
REI
EIDR
QPEI
EIFR
REID
NOF
EIFP
NOISE1
NOFTF
IOCD
DRR
CD
WCD
RNREI
NEIB

```
25C*****************************************************************************
50C
75C VARIABLE LIST FOR THE CONSUMPTION SECTOR
100C
125C BINV    BASE INVENTORY
150C CD      COMMAND DIRECTIVES
175C CRD1    CUMULATIVE RECURRING DEMAND 1
200C DRR     DESIRED READY RATE
225C EIFP    END ITEM FAILURE PARAMETER
250C EIFR    END ITEM FAILURE RATE
275C EIRR    END ITEM REPAIR RATE
300C IOCD    INITIAL OPERATION CAPABLE DATE
325C MRC     MAINTENANCE REPAIR CAPABILITY
350C NEIB    NUMBER OF END ITEMS ON BASE
375C NOF     NUMBER OF FAILURES
400C NOFTF   NUMBER OF FAILURES TIMING FACTOR
425C NOISE1  NOISE 1
450C NREI    NOT READY END ITEMS
475C OPUR    OTHER PARTS USE RATE
500C PURF1   PARTS USE RATE FRACTION 1
525C PURF2   PARTS USE RATE FRACTION 2
550C PURF3   PARTS USE RATE FRACTION 3
575C PUSER   PARTS USE RATE
600C PUSERF  PARTS USE RATE FRACTION
625C QPEI    QUANTITY OF PARTS PER END ITEM
650C REI     READY END ITEMS
675C REID    READY END ITEM DISCREPANCY
700C RNREI   REQUIRED NUMBER OF READY END ITEMS
725C WCD     WING COMMANDER'S DESIRES
750C
775C*****************************************************************************
```

# APPENDIX F

# PROGRAM LISTING

```
25*    A DYNAMIC MODEL OF THE ISSL DEVELOPMENT PROCESS
50NOTE
75NOTE
100NOTE     ISSL DEVELOPMENT SECTOR
125NOTE
150NOTE
175L WISSL.K=WISSL.J+(DT)(WIAR.JK)
200NOTE      WISSL   -WORLDWIDE ISSL
225NOTE      DT      -DELTA TIME
250NOTE      WIAR    -WORLDWIDE ISSL ADJUSTMENT RATE
275R WIAR.KL=WIARF1.K+WIARF2.K
300NOTE      WIAR    -WORLDWIDE ISSL ADJUSTMENT RATE
325NOTE      WIARF1  -WORLDWIDE ISSL ADJUSTMENT RATE FACTOR 1
350NOTE      WIARF2  -WORLDWIDE ISSL ADJUSTMENT RATE FACTOR 2
375A WIARF1.K=(WID1.K)(WTF1.K)(WTF3.K)(1/DT)
400NOTE      WIARF1  -WORLDWIDE ISSL ADJUSTMENT RATE FACTOR 1
425NOTE      WID1    -WORLDWIDE ISSL DISCREPANCY 1
450NOTE      WTF1    -WORLDWIDE ISSL TIMING FACTOR 1
475NOTE      WTF3    -WORLDWIDE ISSL TIMING FACTOR 3
500NOTE      DT      -DELTA TIME
525A WID1.K=IWISSL.K-WISSL.K
550NOTE      WID1    -WORLDWIDE ISSL DISCREPANCY 1
575NOTE      IWISSL  -INITIAL WORLDWIDE ISSL
600NOTE      WISSL   -WORLDWIDE ISSL
625A WTF1.K=CLIP(0,1,TIME.K,WREVT)
650NOTE      WTF1    -WORLDWIDE ISSL TIMING FACTOR 1
675NOTE      TIME    -TIME
700NOTE      WREVT   -WORLDWIDE ISSL REVIEW TIME
725A WTF2.K=CLIP(0,1,WTF1.K,0.5)
750NOTE      WTF2    -WORLDWIDE ISSL TIMING FACTOR 2
775NOTE      WTF1    -WORLDWIDE ISSL TIMING FACTOR 1
800L WTF3.K=CLIP(0,1,WTF2.J,0.5)
825NOTE      WTF3    -WORLDWIDE ISSL TIMING FACTOR 3
850NOTE      WTF2    -WORLDWIDE ISSL TIMING FACTOR 2
875A WIARF2.K=(WID2.K)(WTF2.K)(WTF3.K)(1/DT)
900NOTE      WIARF2  -WORLDWIDE ISSL ADJUSTMENT RATE FACTOR 2
925NOTE      WID2    -WORLDWIDE ISSL DISCREPANCY 2
950NOTE      WTF2    -WORLDWIDE ISSL TIMING FACTOR 2
975NOTE      WTF3    -WORLDWIDE ISSL TIMING FACTOR 3
1000NOTE      DT      -DELTA TIME
1025A WID2.K=(IFOB.K+SMDR.K-WISSL.K)(NOISE2.K)
1050NOTE      WID2    -WORLDWIDE ISSL DISCREPANCY 2
1075NOTE      IFOB    -INPUT FROM OTHER BASES
1100NOTE      SMDR    -SMOOTHED MONTHLY DEMAND RATE
1125NOTE      WISSL   -WORLDWIDE ISSL
1150NOTE      NOISE2  -NOISE 2
```

```
1175A SMDR.K=(3Ø)(SMOOTH(NEWDDR.K,SP))
12ØØNOTE      SMDR    -SMOOTHED MONTHLY DEMAND RATE
1225NOTE      NEWDDR  -NEW DAILY DEMAND RATE
125ØNOTE      SP      -SMOOTHING PERIOD
1275A IFOB.K=(SMDR.K/FEIB.K)-SMDR.K
13ØØNOTE      IFOB    -INPUT FROM OTHER BASES
1325NOTE      SMDR    -SMOOTHED MONTHLY DEMAND RATE
135ØNOTE      FEIB    -FRACTION OF END ITEMS ON BASE
1375A FEIB.K=NEIB/TNEI
14ØØNOTE      FEIB    -FRACTION OF END ITEMS ON BASE
1425NOTE      NEIB    -NUMBER OF END ITEMS ON BASE
145ØNOTE      TNEI    -TOTAL NUMBER OF END ITEMS
1475A NOISE2.K=NORMRN(1.Ø,Ø.2)
15ØØNOTE      NOISE2  -NOISE 2
1525A IWISSL.K=OSTR.K+RCR.K
155ØNOTE      IWISSL  -INITIAL WORLDWIDE ISSL
1575NOTE      OSTR    -ORDER AND SHIP TIME REQUIREMENT
16ØØNOTE      RCR     -REPAIR CYCLE REQUIREMENT
1625A OSTR.K=(BOST.K)(PTMFI.K)(CP.K)
165ØNOTE      OSTR    -ORDER AND SHIP TIME REQUIREMENT
1675NOTE      BOST    -BASE ORDER AND SHIP TIME
17ØØNOTE      PTMFI   -PEAK TOTAL MONTH FIELD ISSUES
1725NOTE      CP      -CONDEMNATION PERCENT
175ØA BOST.K=OST/3Ø   MONTHS
1775NOTE      BOST    -BASE ORDER AND SHIP TIME
18ØØNOTE      OST     -ORDER AND SHIP TIME
1825A RCR.K=(BRC.K)(PTMFI.K)(1.ØØ-CP.K)
185ØNOTE      RCR     -REPAIR CYCLE REQUIREMENT
1875NOTE      BRC     -BASE REPAIR CYCLE
19ØØNOTE      PTMFI   -PEAK TOTAL MONTH FIELD ISSUES
1925NOTE      CP      -CONDEMNATION PERCENT
195ØA PTMFI.K=PTMDRI.K-PTMDOI.K
1975NOTE      PTMFI   -PEAK TOTAL MONTH FIELD ISSUES
2ØØØNOTE      PTMDRI  -PEAK TOTAL MONTH DEMAND RATE ISSUES
2Ø25NOTE      PTMDOI  -PEAK TOTAL MONTH DEPOT OVERHAUL ISSUES
2Ø5ØA PTMDOI.K=(DEPRP.K)(QPEI)(PMP.K)
2Ø75NOTE      PTMDOI  -PEAK TOTAL MONTH DEPOT OVERHAUL ISSUES
21ØØNOTE      DEPRP   -DEPOT REPLACEMENT PERCENT
2125NOTE      QPEI    -QUANTITY OF PARTS PER END ITEM
215ØNOTE      PMP     -PEAK MONTH PROGRAM
2175A PTMDRI.K=(TDRMF.K)(QPEI)(PMP.K)
22ØØNOTE      PTMDRI  -PEAK TOTAL MONTH DEMAND RATE ISSUES
2225NOTE      TDRMF   -TOTAL DEMAND RATE MAINTENANCE FACTOR
225ØNOTE      QPEI    -QUANTITY OF PARTS PER END ITEM
2275NOTE      PMP     -PEAK MONTH PROGRAM
```

```
2300L BISSL.K=BISSL.J+(DT)(BIAR.JK)
2325NOTE      BISSL   -BASE ISSL
2350NOTE      DT      -DELTA TIME
2375NOTE      BIAR    -BASE ISSL ADJUSTMENT RATE
2400R BIAR.KL=BISSLD.K
2425NOTE      BIAR    -BASE ISSL ADJUSTMENT RATE
2450NOTE      BISSLD  -BASE ISSL DISCREPANCY
2475A BISSLD.K=(WISSL.K)(FEIB.K)-BISSL.K
2500NOTE      BISSLD  -BASE ISSL DISCREPANCY
2525NOTE      WISSL   -WORLDWIDE ISSL
2550NOTE      FEIB    -FRACTION OF END ITEMS ON BASE
2575NOTE      BISSL   -BASE ISSL
2600N BISSL=BISSLI
2625NOTE      BISSL   -BASE ISSL
2650NOTE      BISSLI  -BASE ISSL (INITIAL)
2675C BISSLI=10
2700NOTE      BISSLI  -BASE ISSL (INITIAL)
2725C NEIB=100
2750NOTE      NEIB    -NUMBER OF END ITEMS ON BASE
2775C TNEI=500
2800NOTE      TNEI    -TOTAL NUMBER OF END ITEMS
2825N WISSL=WISSLI
2850NOTE      WISSL   -WORLDWIDE ISSL
2875NOTE      WISSLI  -WORLDWIDE ISSL (INITIAL)
2900C WREVT=200
2925NOTE      WREVT   -WORLDWIDE ISSL REVIEW TIME
2950C WISSLI=50
2975NOTE      WISSLI  -WORLDWIDE ISSL (INITIAL)
3000N WTF3=1
3025NOTE      WTF3    -WORLDWIDE ISSL TIMING FACTOR 3
3050C SP=90
3075NOTE      SP      -SMOOTHING PERIOD
3100C OST=12  DAYS
3125NOTE      OST     -ORDER AND SHIP TIME
3150A TDRMF.K=TDRMFI
3175NOTE      TDRMF   -TOTAL DEMAND RATE MAINTENANCE FACTOR
3200NOTE      TDRMFI  -TDRMF (INITIAL)
3225C TDRMFI=1.0
3250NOTE      TDRMFI  -TDRMF (INITIAL)
3275A PMP.K=PMPI
3300NOTE      PMP     -PEAK MONTH PROGRAM
3325NOTE      PMPI    -PMP (INITIAL)
3350C PMPI=63
3375NOTE      PMPI    -PMP (INITIAL)
3400A DEPRP.K=DEPRPI
3425NOTE      DEPRP   -DEPOT REPLACEMENT PERCENT
3450NOTE      DEPRPI  -DEPOT REPLACEMENT PERCENT (INITIAL)
```

```
3475C DEPRPI=0
3500NOTE      DEPRPI  -DEPOT REPLACEMENT PERCENT (INITIAL)
3525A CP.K=CPI
3550NOTE      CP      -CONDEMNATION PERCENT
3575NOTE      CPI     -CONDEMNATION PERCENT (INITIAL)
3600C CPI=1.0
3625NOTE      CPI     -CONDEMNATION PERCENT (INITIAL)
3650A BRC.K=BRCI
3675NOTE      BRC     -BASE REPAIR CYCLE
3700NOTE      BRCI    -BASE REPAIR CYCLE (INITIAL)
3725C BRCI=0
3750NOTE      BRCI    -BASE REPAIR CYCLE (INITIAL)
3775NOTE
3800NOTE
3825NOTE     BASE INVENTORY SECTOR
3850NOTE     (INVENTORY SUBSECTOR)
3875NOTE
3900NOTE
3925L BINV.K=BINV.J+(DT)(BPROCR.JK-PUSER.JK)
3950NOTE      BINV    -BASE INVENTORY
3975NOTE      BPROCR  -BASE PROCUREMENT RATE
4000NOTE      PUSER   -PARTS USE RATE
4025R BPROCR.KL=(EOQ.K)(BFO.K)
4050NOTE      BPROCR  -BASE PROCUREMENT RATE
4075NOTE      EOQ     -BASE ECONOMIC ORDER QUANTITY
4100NOTE      BFO     -BASE FRACTION ORDERED
4125A EOQ.K=((4.4)(SQRT((DDR.K)(VSO)(UP))))/(UP)
4150NOTE      EOQ     -BASE ECONOMIC ORDER QUANTITY
4175NOTE      DDR     -DAILY DEMAND RATE
4200NOTE      VSO     -VARIABLE STOCKAGE OBJECTIVE
4225NOTE      UP      -UNIT PRICE
4250A BFO.K=(BFO1.K)(BFO5.K)(MIN(BFO3.K,BFO4.K))(1/DT)
4275NOTE      BFO     -BASE FRACTION ORDERED
4300NOTE      BFO1    -BASE FRACTION ORDERED 1
4325NOTE      BFO5    -BASE FRACTION ORDERED 5
4350NOTE      BFO3    -BASE FRACTION ORDERED 3
4375NOTE      BFO4    -BASE FRACTION ORDERED 4
4400NOTE      DT      -DELTA TIME
4425A BFO1.K=CLIP(0,1,BINV.K,RP.K)
4450NOTE      BFO1    -BASE FRACTION ORDERED 1
4475NOTE      BINV    -BASE INVENTORY
4500NOTE      RP      -BASE REORDER POINT
4525L BFO2.K=CLIP(0,1,BFO1.J,0.5)
4550NOTE      BFO2    -BASE FRACTION ORDERED 2
4575NOTE      BFO1    -BASE FRACTION ORDERED 1
4600L BFO5.K=CLIP(0,1,BFO2.J,0.5)
4625NOTE      BFO5    -BASE FRACTION ORDERED 5
4650NOTE      BFO2    -BASE FRACTION ORDERED 2
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4675A BF03.K=CLIP(1,(DINV.K/EOQ.K),(DINV.K-EOQ.K),0)
4700NOTE      BF03    -BASE FRACTION ORDERED 3
4725NOTE      DINV    -DEPOT INVENTORY
4750NOTE      EOQ     -BASE ECONOMIC ORDER QUANTITY
4775A BF04.K=CLIP(1,(BMAP.K/CEOQ.K),(BMAP.K-CEOQ.K),0)
4800NOTE      BF04    -BASE FRACTION ORDERED 4
4825NOTE      BMAP    -BASE MONEY AVAILABLE FOR PROCUREMENT
4850NOTE      CEOQ    -COST OF BASE ECONOMIC ORDER QUANTITY
4875A CEOQ.K=(EOQ.K)(UP)
4900NOTE      CEOQ    -COST OF BASE ECONOMIC ORDER QUANTITY
4925NOTE      EOQ     -BASE ECONOMIC ORDER QUANTITY
4950NOTE      UP      -UNIT PRICE
4975A RP.K=MAX((BISSL.K/3),NRP.K)
5000NOTE      RP      -BASE REORDER POINT
5025NOTE      BISSL   -BASE INITIAL SPARES SUPPORT LIST
5050NOTE      NRP     -NORMAL REORDER POINT
5075A NRP.K=OSTQ.K+SLQ.K
5100NOTE      NRP     -NORMAL REORDER POINT
5125NOTE      OSTQ    -ORDER AND SHIP TIME QUANTITY
5150NOTE      SLQ     -SAFETY LEVEL QUANTITY
5175A OSTQ.K=(DDR.K)(OST)
5200NOTE      OSTQ    -ORDER AND SHIP TIME QUANTITY
5225NOTE      DDR     -DAILY DEMAND RATE
5250NOTE      OST     -ORDER AND SHIP TIME
5275A SLQ.K=MAX((C)(SQRT((3)(OSTQ.K))),(DDR.K)(15))
5300NOTE      SLQ     -SAFETY LEVEL QUANTITY
5325NOTE      C       -CONSTANT
5350NOTE      OSTQ    -ORDER AND SHIP TIME QUANTITY
5375NOTE      DDR     -DAILY DEMAND RATE
5400L BMAP.K=BMAP.J+(DT)(BAR.JK-BSR.JK)
5425NOTE      BMAP    -BASE MONEY AVAILABLE FOR PROCUREMENT
5450NOTE      DT      -DELTA TIME
5475NOTE      BAR     -BASE APPROPRIATION RATE
5500NOTE      BSR     -BASE SPENDING RATE
5525R BAR.KL=BSR.JK
5550NOTE      BAR     -BASE APPROPRIATION RATE
5575NOTE      BSR     -BASE SPENDING RATE
5600R BSR.KL=(BPROCR.JK)(UP)
5625NOTE      BSR     -BASE SPENDING RATE
5650NOTE      BPROCR  -BASE PROCUREMENT RATE
5675NOTE      UP      -UNIT PRICE
5700N BINV=BINVI
5725NOTE      BINV    -BASE INVENTORY
5750NOTE      BINVI   -BASE INVENTORY (INITIAL)
5775C BINVI=200
5800NOTE      BINVI   -BASE INVENTORY (INITIAL)
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5825C VSO=180
5850NOTE      VSO     -VARIABLE STOCKAGE OBJECTIVE
5875C C=1
5900NOTE      C       -CONSTANT
5925N BFO2=1
5950NOTE      BFO2    -BASE FRACTION ORDERED 2
5975N BFO5=0
6000NOTE      BFO5    -BASE FRACTION ORDERED 5
6025N BMAP=BMAPI
6050NOTE      BMAP    -BASE MONEY AVAILABLE FOR PROCUREMENT
6075NOTE      BMAPI   -BASE MONEY AVAILABLE FOR PROCUREMENT (INITIAL)
6100C BMAPI=500
6125NOTE      BMAPI   -BASE MONEY AVAILABLE FOR PROCUREMENT (INITIAL)
6150C UP=.5
6175NOTE      UP      -UNIT PRICE
6200NOTE
6225NOTE
6250NOTE                 BASE INVENTORY SECTOR
6275NOTE            (DAILY DEMAND RATE ADJUSTMENT SUBSECTOR)
6300NOTE
6325NOTE
6350L DDR.K=DDR.J+(DT)(DDRAR.JK)
6375NOTE      DDR     -DAILY DEMAND RATE
6376NOTE      DT      -DELTA TIME
6377NOTE      DDRAR   -DAILY DEMAND RATE ADJUSTMENT RATE
6400R DDRAR.KL=DDRAF.K
6425NOTE      DDRAR   -DAILY DEMAND RATE ADJUSTMENT RATE
6450NOTE      DDRAF   -DAILY DEMAND RATE ADJUSTMENT FACTOR
6475A DDRAF.K=(DDRD.K)(BFO1.K)(BFO2.K)(ARF1.K)(1/DT)
6500NOTE      DDRAF   -DAILY DEMAND RATE ADJUSTMENT FACTOR
6525NOTE      DDRD    -DAILY DEMAND RATE DISCREPANCY
6550NOTE      BFO1    -BASE FRACTION ORDERED 1
6575NOTE      BFO2    -BASE FRACTION ORDERED 2
6600NOTE      ARF1    -ADJUSTMENT RATE FACTOR 1
6625NOTE      DT      -DELTA TIME
6650A DDRD.K=NEWDDR.K-DDR.K
6675NOTE      DDRD    -DAILY DEMAND RATE DISCREPANCY
6700NOTE      NEWDDR  -NEW DAILY DEMAND RATE
6725NOTE      DDR     -DAILY DEMAND RATE
6750A NEWDDR.K=CRD.K/NDAYS2.K
6775NOTE      NEWDDR  -NEW DAILY DEMAND RATE
6800NOTE      CRD     -CUMULATIVE RECURRING DEMAND
6825NOTE      NDAYS2  -NUMBER OF DAYS 2
6850C REVPI=45    DAYS
6875NOTE      REVPI   -REVIEW PERIOD (INITIAL)
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6900FOR I=1,REVPI
6925NOTE      I        -REVIEW PERIOD COUNTER
6950NOTE      REVPI    -REVEIW PERIOD (INITIAL)
6975A CRD.K=SUM(CRD1.K)
6976NOTE      CRD      -CUMULATIVE RECURRING DEMAND
7000NOTE      CRD1     -CUMULATIVE RECURRING DEMAND 1
7025L CRD1.K(I)=(PUSER.JK)(DT)+CRD1.J(I)
7050NOTE      CRD1     -CUMULATIVE RECURRING DEMAND 1
7075NOTE      PUSER    -PARTS USE RATE
7100NOTE      DT       -DELTA TIME
7125A NDAYS2.K=CLIP(NDAYS1.K,1,NDAYS1.K,1)
7150NOTE      NDAYS2   -NUMBER OF DAYS 2
7175NOTE      NDAYS1   -NUMBER OF DAYS 1
7200A NDAYS1.K=CLIP(REVP.K,TIME.K,TIME.K,REVP.K)
7225NOTE      NDAYS1   -NUMBER OF DAYS 1
7250NOTE      REVP     -REVIEW PERIOD
7275NOTE      TIME     -TIME
7300A ARF1.K=CLIP(1,0,(AVDISC.K-SQRT(EBIL.K)),0)
7325NOTE      ARF1     -ADJUSTMENT RATE FACTOR 1
7350NOTE      AVDISC   -ABSOLUTE VALUE OF DISC
7375NOTE      EBIL     -ESTABLISHED BASE INVENTORY LEVEL
7400A DISC.K=EOQDL.K-EBIL.K
7425NOTE      DISC     -DISCREPANCY
7450NOTE      EOQDL    -BASE EOQ DEMAND LEVEL
7475NOTE      EBIL     -ESTABLISHED BASE INVENTORY LEVEL
7500A AVDISC.K=MAX(DISC.K,-DISC.K)
7525NOTE      AVDISC   -ABSOLUTE VALUE OF DISC
7550NOTE      DISC     -DISCREPANCY
7575A EOQDL.K=EOQ1.K+OSTQ1.K+SLQ1.K
7600NOTE      EOQDL    -BASE EOQ DEMAND LEVEL
7625NOTE      EOQ1     -BASE ECONOMIC ORDER QUANTITY 1
7650NOTE      OSTQ1    -ORDER AND SHIP TIME QUANTITY 1
7675NOTE      SLQ1     -SAFETY LEVEL QUANTITY 1
7700A EOQ1.K=((4.4)(SQRT((NEWDDR.K)(VSO)(UP))))/(UP)
7725NOTE      EOQ1     -BASE ECONOMIC ORDER QUANTITY 1
7750NOTE      NEWDDR   -NEW DAILY DEMAND RATE
7775NOTE      VSO      -VARIABLE STOCKAGE OBJECTIVE
7800NOTE      UP       -UNIT PRICE
7825A OSTQ1.K=(NEWDDR.K)(OST)
7850NOTE      OSTQ1    -ORDER AND SHIP TIME QUANTITY 1
7875NOTE      NEWDDR   -NEW DAILY DEMAND RATE
7900NOTE      OST      -ORDER AND SHIP TIME
7925A SLQ1.K=MAX((C)(SQRT((3)(OSTQ1.K))),(NEWDDR.K)(15))
7950NOTE      SLQ1     -SAFETY LEVEL QUANTITY 1
7975NOTE      C        -CONSTANT
8000NOTE      OSTQ1    -ORDER AND SHIP TIME QUANTITY 1
8025NOTE      NEWDDR   -NEW DAILY DEMAND RATE
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8050L EBIL.K=EBIL.J+(DT)(EBILAR.JK)
8075NOTE      EBIL    -ESTABLISHED BASE INVENTORY LEVEL
8100NOTE      DT      -DELTA TIME
8125NOTE      EBILAR  -EBIL ADJUSTMENT RATE
8150R EBILAR.KL=(1/DT)(ARF.K)
8175NOTE      EBILAR  -EBIL ADJUSTMENT RATE
8200NOTE      DT      -DELTA TIME
8225NOTE      ARF     -ADJUSTMENT RATE FACTOR
8250A ARF.K=(ARF4.K-EBIL.K)(ATF.K)
8275NOTE      ARF     -ADJUSTMENT RATE FACTOR
8300NOTE      ARF4    -ADJUSTMENT RATE FACTOR 4
8325NOTE      EBIL    -ESTABLISHED BASE INVENTORY LEVEL
8350NOTE      ATF     -ADJUSTMENT TIMING FACTOR
8375A ATF.K=(BFO1.K)(BFO2.K)
8400NOTE      ATF     -ADJUSTMENT TIMING FACTOR
8425NOTE      BFO1    -BASE FRACTION ORDERED 1
8450NOTE      BFO2    -BASE FRACTION ORDERED 2
8475A ARF4.K=SWITCH((ARF2.K+EBIL.K),
8500X (MAX(ARF2.K+EBIL.K,ABISSL.K)),ABISSL.K)
8525NOTE      ARF4    -ADJUSTMENT RATE FACTOR 4
8550NOTE      ARF2    -ADJUSTMENT RATE FACTOR 2
8575NOTE      EBIL    -ESTABLISHED BASE INVENTORY LEVEL
8600NOTE      ABISSL  -ADJUSTED BASE ISSL
8625A ABISSL.K=(BAB)(BISSL.K)(ABTF.K)
8650NOTE      ABISSL  -ADJUSTED BASE ISSL
8675NOTE      BAB     -BASE ADJUSTMENT TO THE BASE ISSL
8676NOTE      BISSL   -BASE ISSL
8700NOTE      ABTF    -ADJUSTED BASE ISSL TIMING FACTOR
8725A ABTF.K=STEP(1,ABTFST)+STEP(-1,IOCD+730)
8750NOTE      ABTF    -ADJUSTED BASE ISSL TIMING FACTOR
8775NOTE      ABTFST  -ABTF STEP TIME
8800NOTE      IOCD    -INITIAL OPERATION CAPABLE DATE
8825A ARF2.K=(MIN(AVDISC.K,MAXCHG.K))(ARF1.K)(ARF5.K)
8850NOTE      ARF2    -ADJUSTMENT RATE FACTOR 2
8875NOTE      AVDISC  -ABSOLUTE VALUE OF DISC
8900NOTE      MAXCHG  -MAXIMUM CHANGE
8925NOTE      ARF1    -ADJUSTMENT RATE FACTOR 1
8950NOTE      ARF5    -ADJUSTMENT RATE FACTOR 5
8975A ARF5.K=CLIP(1,-1,DISC.K,0)
9000NOTE      ARF5    -ADJUSTMENT RATE FACTOR 5
9025NOTE      DISC    -DISCREPANCY
9050A MAXCHG.K=SQRT(EBIL.K)
9075NOTE      MAXCHG  -MAXIMUM CHANGE
9100NOTE      EBIL    -ESTABLISHED BASE INVENTORY LEVEL
9125N DDR=DDRI
9150NOTE      DDR     -DAILY DEMAND RATE
9175NOTE      DDRI    -DAILY DEMAND RATE (INITIAL)
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92ØØC DDRI=3
9225NOTE      DDRI    -DAILY DEMAND RATE (INITIAL)
925ØA REVP.K=REVPI
9275NOTE      REVP    -REVIEW PERIOD
93ØØNOTE      REVPI   -REVIEW PERIOD (INITIAL)
9325N CRD1(I)=Ø
935ØNOTE      CRD1    -CUMULATIVE RECURRING DEMAND 1
9375A OUT.K=SHIFTL(CRD1.K,INTVL)
94ØØNOTE      OUT     -DISCRETE OUTPUT OF CRD1 ARRAY
9425NOTE      CRD1    -CUMULATIVE RECURRING DEMAND 1
945ØNOTE      INTVL   -CRD1 ARRAY SHIFT INTERVAL
9475C ABTFST=Ø
95ØØNOTE      ABTFST  -ABTF STEP TIME
9525C BAB=1
955ØNOTE      BAB     -BASE ADJUSTMENT TO THE BASE ISSL
9575C INTVL=1
96ØØNOTE      INTVL   -INTERVAL
9625N EBIL=EBILI
965ØNOTE      EBIL    -ESTABLISHED BASE INVENTORY LEVEL
9675NOTE      EBILI   -ESTABLISHED BASE INVENTORY LEVEL (INITIAL)
97ØØC EBILI=2ØØ
9725NOTE      EBILI   -ESTABLISHED BASE INVENTORY LEVEL (INITIAL)
975ØNOTE
9775NOTE
98ØØNOTE        DEPOT INVENTORY SECTOR
9825NOTE
985ØNOTE
9875L DINV.K=DINV.J+(DT)(DPROCR.JK-BPROCR.JK)
99ØØNOTE     DINV    -DEPOT INVENTORY
9925NOTE     DPROCR  -DEPOT PROCUREMENT RATE
995ØNOTE     BPROCR  -BASE PROCUREMENT RATE
9975R DPROCR.KL=(DEOQ.K)(DFO.K)
1ØØØØNOTE     DPROCR  -DEPOT PROCUREMENT RATE
1ØØ25NOTE     DEOQ    -DEPOT ECONOMIC ORDER QUANTITY
1ØØ5ØNOTE     DFO     -DEPOT FRACTION ORDERED
1ØØ75A DEOQ.K=(5)(EOQ.K)
1Ø1ØØNOTE     DEOQ    -DEPOT ECONOMIC ORDER QUANTITY
1Ø125NOTE     EOQ     -BASE ECONOMIC ORDER QUANTITY
1Ø15ØA DFO.K=(DFO1.K)(DFO2.K)(DFO4.K)
1Ø175NOTE     DFO     -DEPOT FRACTION ORDERED
1Ø2ØØNOTE     DFO1    -DEPOT FRACTION ORDERED 1
1Ø225NOTE     DFO2    -DEPOT FRACTION ORDERED 2
1Ø25ØNOTE     DFO4    -DEPOT FRACTION ORDERED 4
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10275A DFO1.K=CLIP(0,(1/DT),DINV.K,DRP.K)
10300NOTE      DFO1     -DEPOT FRACTION ORDERED 1
10325NOTE      DT       -DELTA TIME
10350NOTE      DINV     -DEPOT INVENTORY
10375NOTE      DRP      -DEPOT REORDER POINT
10400L DFO2.K=CLIP(0,1,DFO1.J,0.5)
10425NOTE      DFO2     -DEPOT FRACTION ORDERED 2
10450NOTE      DFO1     -DEPOT FRACTION ORDERED 1
10475A DRP.K=(5)(RP.K)
10500NOTE      DRP      -DEPOT REORDER POINT
10525NOTE      RP       -BASE REORDER POINT
10550A DFO4.K=CLIP(1,(DMAP.K/CDEOQ.K),(DMAP.K-CDEOQ.K),0)
10575NOTE      DFO4     -DEPOT FRACTION ORDERED 4
10600NOTE      DMAP     -DEPOT MONEY AVAILABLE FOR PROCUREMENT
10625NOTE      CDEOQ    -COST OF DEPOT ECONOMIC ORDER QUANTITY
10650A CDEOQ.K=(DEOQ.K)(UP)
10675NOTE      CDEOQ    -COST OF DEPOT ECONOMIC ORDER QUANTITY
10700NOTE      DEOQ     -DEPOT ECONOMIC ORDER QUANTITY
10725NOTE      UP       -UNIT PRICE
10750L DMAP.K=DMAP.J+(DT)(DAR.JK-DSR.JK)
10775NOTE      DMAP     -DEPOT MONEY AVAILABLE FOR PROCUREMENT
10800NOTE      DT       -DELTA TIME
10825NOTE      DAR      -DEPOT APPROPRIATION RATE
10850NOTE      DSR      -DEPOT SPENDING RATE
10875R DAR.KL=DSR.JK
10900NOTE      DAR      -DEPOT APPROPRIATION RATE
10925NOTE      DSR      -DEPOT SPENDING RATE
10950R DSR.KL=(DPROCR.JK)(UP)
10975NOTE      DSR      -DEPOT SPENDING RATE
11000NOTE      DPROCR   -DEPOT PROCUREMENT RATE
11025NOTE      UP       -UNIT PRICE
11050N DINV=(5)(BINVI)
11075NOTE      DINV     -DEPOT INVENTORY
11100NOTE      BINVI    -BASE INVENTORY (INITIAL)
11125N DFO2=1
11150NOTE      DFO2     -DEPOT FRACTION ORDERED 2
11175N DMAP=(5)(BMAPI)
11200NOTE      DMAP     -DEPOT MONEY AVAILABLE FOR PROCUREMENT
11225NOTE      BMAPI    -BASE MONEY AVAILABLE FOR PROCUREMENT (INITIAL)
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11250NOTE
11275NOTE
11300NOTE     CONSUMPTION SECTOR
11325NOTE
11350NOTE
11375L REI.K=REI.J+(DT)(EIRR.JK-EIFR.JK)
11400NOTE      REI     -READY END ITEMS
11425NOTE      DT      -DELTA TIME
11450NOTE      EIRR    -END ITEM REPAIR RATE
11475NOTE      EIFR    -END ITEM FAILURE RATE
11500R EIRR.KL=(PUSER.JK/QPEI)
11525NOTE      EIRR    -END ITEM REPAIR RATE
11550NOTE      PUSER   -PARTS USE RATE
11575NOTE      QPEI    -QUANTITY OF PARTS PER END ITEM
11600R EIFR.KL=NOF.K
11625NOTE      EIFR    -END ITEM FAILURE RATE
11650NOTE      NOF     -NUMBER OF FAILURES
11675R PUSER.KL=(NREI.K)(QPEI)(PUSERF.K)+OPUR
11700NOTE      PUSER   -PARTS USE RATE
11725NOTE      NREI    -NOT READY END ITEMS
11750NOTE      QPEI    -QUANTITY OF PARTS PER END ITEM
11775NOTE      PUSERF  -PARTS USE RATE FACTOR
11800NOTE      OPUR    -OTHER PARTS USE RATE
11825A NREI.K=NEIB-REI.K
11850NOTE      NREI    -NOT READY END ITEMS
11875NOTE      NEIB    -NUMBER OF END ITEMS ON BASE
11900NOTE      REI     -READY END ITEMS
11925A PUSERF.K=(MIN(PURF1.K,PURF3.K))(PURF2.K)
11950NOTE      PUSERF  -PARTS USE RATE FRACTION
11975NOTE      PURF1   -PARTS USE RATE FRACTION 1
12000NOTE      PURF3   -PARTS USE RATE FRACTION 3
12025NOTE      PURF2   -PARTS USE RATE FRACTION 2
12050A PURF1.K=CLIP(1,(BINV.K/(NREI.K)(QPEI)),(BINV.K-
12075X (NREI.K)(QPEI)),0)
12100NOTE      PURF1   -PARTS USE RATE FRACTION 1
12125NOTE      BINV    -BASE INVENTORY
12150NOTE      NREI    -NOT READY END ITEMS
12175NOTE      QPEI    -QUANTITY OF PARTS PER END ITEM
12200A PURF2.K=TABHL(PURF2T,REID.K,-10,1,1)
12225NOTE      PURF2   -PARTS USE RATE FRACTION 2
12250NOTE      PURF2T  -PARTS USE RATE FRACTION 2 TABLE
12275NOTE      REID    -READY END ITEM DISCREPANCY
12300A PURF3.K=CLIP(1,(MRC/NREI.K),(MRC-NREI.K),0)
12325NOTE      PURF3   -PARTS USE RATE FRACTION 3
12350NOTE      MRC     -MAINTENANCE REPAIR CAPABILITY
12375NOTE      NREI    -NOT READY END ITEMS
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12400A REID.K=RNREI.K-REI.K
12425NOTE      REID    -READY END ITEM DISCREPANCY
12450NOTE      RNREI   -REQUIRED NUMBER OF READY END ITEMS
12475NOTE      REI     -READY END ITEMS
12500A RNREI.K=(DRR.K)(NEIB)
12525NOTE      RNREI   -REQUIRED NUMBER OF READY END ITEMS
12550NOTE      DRR     -DESIRED READY RATE
12575NOTE      NEIB    -NUMBER OF END ITEMS ON BASE
12600A DRR.K=CD+WCD
12625NOTE      DRR     -DESIRED READY RATE
12650NOTE      CD      -COMMAND DIRECTIVES
12675NOTE      WCD     -WING COMMANDER'S DESIRES
12700A NOF.K=(REI.K)(EIFP)(NOISE1.K)(NOFTF.K)
12725NOTE      NOF     -NUMBER OF FAILURES
12750NOTE      REI     -READY END ITEMS
12775NOTE      EIFP    -END ITEM FAILURE PARAMETER
12800NOTE      NOISE1  -NOISE 1
12825NOTE      NOFTF   -NUMBER OF FAILURES TIMING FACTOR
12850A NOFTF.K=STEP(1,IOCD)
12875NOTE      NOFTF   -NUMBER OF FAILURES TIMING FACTOR
12900NOTE      IOCD    -INITIAL OPERATION CAPABLE DATE
12925A NOISE1.K=NORMRN(1.0,0.2)
12950NOTE      NOISE1  -NOISE 1
12975N REI=REII
13000NOTE      REI     -READY END ITEMS
13025NOTE      REII    -READY END ITEMS (INITIAL)
13050C REII=98
13075NOTE      REII    -READY END ITEMS (INITIAL)
13100C QPEI=2
13125NOTE      QPEI    -QUANTITY OF PARTS PER END ITEM
13150C OPUR=0
13175NOTE      OPUR    -OTHER PARTS USE RATE
13200T PURF2T=.3/.3/.35/.4/.5/.66/.8/.9/.98/1./1./1.
13225NOTE      PURF2T  -PARTS USE RATE FRACTION 2 TABLE
13250C IOCD=0
13275NOTE      IOCD    -INITIAL OPERATION CAPABLE DATE
13300C EIFP=.0167   PER DAY
13325NOTE      EIFP    -END ITEM FAILURE PARAMETER
13350C MRC=4
13375NOTE      MRC     -MAINTENANCE RAPAIR CAPABILITY
13400C CD=.85
13425NOTE      CD      -COMMAND DIRECTIVES
13450C WCD=.05
13475NOTE      WCD     -WING COMMANDER'S DESIRES
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13500NOTE
13525NOTE
13550NOTE       CONTROL CARDS
13575NOTE
13600NOTE
13625PLOT DINV=I/DPROCR=P/DRP=R/DEOQ=E/DF01=1/DF02=2/DF04=4/DF0=*
13650PLOT BINV=I/BPROCR=P/RP=R/EOQ=E/BF01=1/BF02=2/BF03=3/BF04=4/
13675X BF05=5/BF0=*
13700PLOT DDR=D/CRD=C/NEWDDR=N/SMDR=S/NDAYS2=Z
13725PLOT EBIL=E/ARF1=1/ARF2=2/ARF4=4/ARF5=5/ARF=A/EOQDL=Q/
13750X DISC=X/MAXCHG=M
13775PLOT BISSL=B/WISSL=W/WIARF1=1/WIARF2=2/WIAR=A/
13800X IWISSL=*/SMDR=S/WTF1=X/WTF2=Y/WTF3=Z
13825PLOT PUSER=P/EIRR=R/EIFR=F/REI=*/NREI=N/PURF1=1/
13850X PURF2=2/PURF3=3/PUSERF=U
13875SPEC DT=1/LENGTH=360/PLTPER=1
13900RUN
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